Occupational Risk Assessment and Management in workplaces with possible presence of Asbestos Containing Materials: the substantial contribution of Image Analysis

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The residual presence of critical components (e.g. Asbestos Containing Materials – ACMs) still represents one of the main criticalities for the Occupational Safety and Health – OS&H in many large public facilities.
The very first step for an effective Risk Assessment and Management is obviously a clear definition of the different approaches, complying with the Italian general and special OS&H regulations, both in scenarios where is confirmed the absence of ACMs, and in those where Hazard modes could be Dormant, Armed, or Active.
A research project, encouraged since 2008 by Politecnico di Torino and Universita' degli Studi di Torino, led to the issuing of a Guideline for Occupational Safety in Universities and large public facilities, and its sub-parts, covering special criticalities. Both the Guideline and sub-parts passed a thorough validation process of extended field tests before approval and dissemination.
The paper covers the third and final step – following a) the Canvassing based Hazard Identification technique (of general use, but particularly effective to investigate the presence of critical materials), and b) the discussion on the role of the airborne fibers measurements – of the study for the "asbestos" sub-part of the Guideline, and deals in particular with the substantial improvement made possible by Image Analysis techniques both in the Risk Assessment, and in the Safety and Health quality Management.
***Keywords**: Occupational Safety and Health, Asbestos Risk Assessment and Management, Quality approach to OS&H, Asbestos Containing Materials, PoliTo-UniTo OS&H Guideline, OS&H Guideline-asbestos sub-part, OS&H in large public facilities, Dissemination of the Culture of Safety.*

***Valutazione e Gestione del Rischio Occupazionale in luoghi di lavoro con possibile presenza di Materiali Contenenti Amianto: il contributo essenziale dell'Analisi di Immagine.** La presenza residuale di componenti critici (ad esempio i Materiali Contenenti Amianto – MCA) rappresenta ancora oggi una delle principali criticità per la Sicurezza e la Salute sul lavoro – OS&H in molte grandi strutture accessibili al pubblico.*
Il primo passo per una efficace Valutazione e Gestione del rischio è chiaramente una rigorosa definizione dei diversi approcci che occorre adottare, in conformità con le normative italiane generali e speciali di OS&H, a partire da scenari in cui l'assenza di MCA può essere dimostrata, e via via nelle varie condizioni in cui si presenta il Fattore di pericolo, da dormiente, ad armato, ad attivo.
Un progetto di ricerca, incoraggiato sin dal 2008 dal Politecnico di Torino e dall'Università degli Studi di Torino, ha portato alla stesura di una Linea Guida per la sicurezza sul lavoro nelle Università e grandi strutture pubbliche, e delle sue sotto-parti, messe a punto per fornire efficaci metodologie di approccio a varie criticità specifiche. Sia la Linea Guida, sia le sotto-parti sono state sistematicamente validate attraverso estesi test sul campo prima della approvazione e diffusione.
Il presente lavoro riferisce sulla impostazione e sui risultati del terzo e ultimo passo – dopo la tecnica di identificazione dei Fattori di pericolo basata su metodiche di Ingegneria Forense (Canvassing) di uso generale ma particolarmente adatta alla problematica in oggetto, e la discussione sul ruolo delle determinazioni di concentrazione delle fibre aerodisperse – dello studio sviluppato per la sotto-parte "amianto" della Linea Guida, e discute del sostanziale mi-

1. Introduction

The residual presence of some critical components, and in particular of Asbestos Containing Materials – ACMs) represents one of the main Occupational Safety and Health – OS&H criticalities in many large public facilities. Due to the impressive number of uses of asbestos in the past, from the beginning of last century, and in particular from the end of WW2, to the official ban, in 1992 (Italian Law 257/92), we still can identify some ACMs in:

a: *shell, systems and interior spaces of settlements containing workplaces*;
b: *work equipment*.

A multidisciplinary research project, encouraged since 2008 by Politecnico di Torino and Universita' degli Studi di Torino, led to the issuing of a Guideline for Occupational Safety and Health in Universities and large public facilities (employees, students and people occasionally involved in the research university activities included), completed with a quality approach, and in full agreement with the OS&H national regulations (basically Legislative Decree 81/08, Italian enforcement of the framework EEC Directive 89/391 *on the introduction of measures to*

glioramento, tanto nella Valutazione del rischio quanto nella Gestione in qualità della sicurezza e della salute del lavoro, reso possibile dall'impiego di tecniche di Analisi di Immagine.
Parole chiave: *Sicurezza e Salute del Lavoro, Valutazione e Gestione del Rischio Amianto, Approccio in Qualità all'OS&H, Materiali Contenenti Amianto, Linea Guida PoliTo-UniTo per la sicurezza sul lavoro, Linea Guida PoliTo-UniTo – sottofase amianto, Disseminazione della Cultura della Sicurezza.*

encourage improvements in the safety and health of workers at work[1]). The Guideline was officially recognized by mutual agreement as "*a basic methodological reference for the Occupational Risk Assessment and Management in large complex structures*" in 2011 (Inter University Meeting, June, 06, 2011) and quoted as basic reference in the Framework agreement between Politecnico di Torino and Universita' degli Studi di Torino, concerning the collaboration to improve the Safety and Health of workers (March, 10, 2015). Both the Guideline and its sub-parts covering special criticalities, passed a thorough validation process of extended field tests aimed to verify both feasibility and exhaustiveness in different real situations before their approval and dissemination (Borchiellini et al., 2015).

A sub-part of the PoliTo-UniTo Guideline, consistent with the Guideline principia, i.e. systematic, complete and formalizable (originally from Center for Chemical Process Safety, 1992), focuses on the Risk of exposure to air-dispersed respirable asbestos fibers. The "*asbestos*" sub-part is based on the results of a research sub-project (2014-2017), and covers different scenarios, ranging from confirmed absence of asbestos, to the various Hazard modes, from Dormant, to Armed, to Active (Occupational Safety and Health Administration, 1991).

A basic point of the "*asbestos*" sub-part approach, The Authors emphasized from the very beginning, is that no undue exposure to asbestos fibers in common work environments is acceptable; hence, consistently with what suggested by Health and Safety Authority – HSA (2013), the "*asbestos*" sub-part distinguishes between:

- *'Non-friable asbestos'*, material containing asbestos that is resistant to mild abrasion and damage and less likely to release inhalable fibres (labelled as *compact matrix* in the "asbestos" sub part of the Guideline);
- *'Friable asbestos'*, an ACM less resistant to mild abrasion or damage and more likely to release inhalable fibres.

Moreover, it shares the statement *"If ACMs are in good condition and left undisturbed, it is unlikely that airborne asbestos will be released into the air, and therefore the risk to health is extremely low. It is usually safer to leave it and review its condition over time. However, if the asbestos or ACM has deteriorated, been disturbed, or if asbestos-contaminated dust is present, the likelihood that airborne asbestos fibres will be released into the air is increased"*.

On these basis, the "*asbestos*" sub-part provides:

– Univocal criteria for a strict classification of workplaces in categories well defined in terms of asbestos Hazard mode;
– A reliable and well-tested reference for the hazard identification phase both in shell, systems and interior spaces, and in work equipment, in terms of presence and conservation conditions of the ACMs and their sealing/enclosures;
– Reliable reference on the risk assessment and management for the prevention of occupational illness from exposure to respirable asbestos fibers of people at work in universities and large public facilities.

2. The essential parts of the "asbestos" sub-part of the Guideline

2.a. Univocal criteria for a strict classification of workplaces in categories well defined in terms of asbestos Hazard mode

Table 1 summarizes the 5 classes of ascription of the building areas suspect for presence of ACMs, the classification of each area resulting from a thorough Hazard Identification process. The result of the first inspection in every area requires systematic confirmation, since the ACMs and sealing/enclosure status can worsen along the time, compromising the initial assumption.

2.b. A reliable and well-tested reference for the Hazard Identification phase both in shell, systems and interior spaces, and in work equipment, in terms of presence and conservation conditions of the ACMs and their sealing/enclosures

A first rough distinction between areas can be based on a *document search*, through the analysis of the building original project and of the additional documents concerning structural modifications, improvements and maintenance: as stated, asbestos was widely used from the beginning of last century, and in particular from the end of WW2, to the official ban, in 1992. Special care should be devoted to the identification of the possi-

[1] D.M. 363/1998, even if still in force, refers to a regulation prior to DLgs.81/08, and is somehow inconsistent with the present reality of Italian top research universities.

Nature of Hazard	Criticality	Criticality Level
Absent	*the ACMs absence, resulting from documents analysis, is confirmed by in situ surveys;*	White
Dormant	*confirmed ACMs presence exclusively in a persisting situation of compact matrix in good conservation conditions, rigorously sealed/enclosed;*	Green
Armed - 1 transition to active status is proven unlikely	*confirmed ACMs presence exclusively in compact matrix in good conservation conditions, located in areas out of common reach and not subject to stress actions potentially causing degradation effects;*	Yellow
Armed - 2 transition to active status without notice is possible	*confirmed ACMs presence exclusively in compact matrix in good conservation conditions or sealed/enclosed, but exposed to stress actions potentially causing degradation effects;*	Red
Active	*confirmed ACMs presence in friable matrix, and/or deteriorated sealing/enclosure.*	Black

Tab. 1. Classes of ascription of the areas depending on the Hazard mode.
Classi di ascrizione delle aree in funzione della condizione del Fattore di pericolo presente.

ble presence of mobile artefacts/equipment, through an inventory check. However, if the document search does not allow to exclude with certainty the presence of ACMs, the area should be included in the Hazard Identification program special for ACMs.

As to the Hazard Identification program special for ACMs, the "asbestos" sub-part of the Guideline suggests the Canvassing (an ad hoc modified Forensic Investigation technique), able to ensure a thorough Hazard Investigation, and an objective reference to assess any worsening of the situation the time passing.

"Risk analysis relies on a structured and systematic approach, starting from the Hazard and Exposure Identification phase, characterized by the largest potential for errors due to a poor identification of hazardous agents/materials characterizing the process. This phase is also a basic part of the Quality Management of process and systems (hence, the revision of Hazard Identification process when system changes occur should never be underestimated)": these considerations lead to verify the possible use of Forensic Investigation techniques (see e.g. International Association of Chiefs of Police and the Federal Law Enforcement Training Center, 2010, and Miller, 2011) for the Occupational Safety & Health Risk Assessment and Management (Borchiellini et al, 2016). The following positive aspects can be highlighted:

1. *In OS&H field, canvassing is particularly suitable for the analysis of shell, services and interior spaces of settlements containing workplaces, and of their not-operative content;*
2. *Canvassing avoids incurring errors due to the judgment subjectivity of the analyst, who may act in accordance with his own preconceived and possibly misleading criteria, or with questionable checklists. On this basis, also the collection of material samples for subsequent laboratory analysis (according to the d.M. 06/09/94) becomes exhaustive;*
3. *Canvassing can make possible a thorough referencing of the results, the detail depending on the quality and suitability of the storage and sharing systems available. Then, they ensure the repeatability of the analysis in conditions under control.*

2.c. Reliable reference on the Risk Assessment and quality Management for the prevention of occupational illness from exposure to respirable asbestos fibers of people at work in Universities and large public facilities

Table 2 summarizes the management criteria of the different classified areas. In particular, the status of Green and Yellow classified areas (respectively dormant, or armed with proven unlikely transition to active status) is the most difficult to confirm: consistent with the D.M. 06/09/94, thorough visual inspections of the artefacts conditions are necessary, whilst, as discussed in (Fargione et al., 2019), airborne fibers concentration measurements cannot provide useful information where no massive emissions are caused by stressing actions on friable ACMs.

3. The substantial contribution of Image Analysis for ACMs Hazard Identification, and ACMs and sealing/enclosures status confirmation along the time

Clear limits of the visual inspection approach, both in the first Hazard Identification phase and in the following inspections aimed to verify the ACMs and sealing/enclosures status, can be: a) a limited quality in the deriving documentation, b) the unsatisfactory detail in the comparison of the AMCs and sealing/enclosures sta-

Area Criticality Level of ascription	OS&H Management Criteria general quality requirement: more so in the asbestos case, a record should be available of activities and results, based on documents on the area, fittings and equipment history, updated mapping, measurement results, collected and processed photographic documentation, involved activities and procedures, etc.
White	*every artefact/material introduced into the area should be labelled asbestos free to preserve the safe condition*
Green	*the green level needs systematic confirmation: this entails thorough inspections (NOTE 1) of the artefacts conservation conditions, periodically and when necessary, i.e. in response to occurrences potentially causing alterations of artefacts or sealing/enclosure (e.g. vibrations from natural causes or human activities, plumbing leakages,...);*
Yellow	*more so in this case, a systematic confirmation is necessary: in addition to the green area confirmation criteria, any modification in the use of the areas potentially compromising the clause "out of common reach and not subject to stress actions potentially causing degradation effects" should be considered, and special procedures defined for routine and exceptional activities in the whole yellow area. Such procedures, based on special risk analysis, should ensure no modifications in the Hazard factor conditions, and in no case cover activities directly involving the ACM or jeopardizing their sealing/enclosure (NOTE 2);*
Red	*any access into the red area of people covered by the Guideline is prohibited prior to the area reclassification through asbestos removal or sealing/enclosure (only licensed contractors are entitled to operate into the red area);*
Black	*the black condition, involving asbestos removal or sealing/enclosure, is not covered by the Guideline: only licensed contractors are entitled to operate into the area.*
(NOTE 1) independent from the area classification, inspection activities should be carried out in safe conditions according to the OS&H general and special regulations; *(NOTE 2) such activities pertain exclusively to the management of black areas, not covered by the Guideline.*	

Tab. 2. Management approaches for the different categorized areas.
Approcci per la Gestione delle differenti aree classificate.

tus along the time, and the possible subjectivity in that evaluation.

A special research sub-project confirmed the substantial improvement achievable thanks to the use of Image Analysis techniques in terms of documentation for the identified ACMs, resulting in a kind of *Identity Card* for each artefact, and in terms of reduction of subjectivity in the decision making process.

3.1. Image Analysis techniques

The implementation of Image Analysis techniques follows the logical flow summarized in Table 3.

3.2. Image Analysis special for the "asbestos" subpart of the Guideline

Some special Image Analysis techniques, involving laser-scanner acquisitions of the investigated areas, and high-resolution digital images of the identified points of interests, were intro-

1. Data acquisition *The data acquisition is designed depending on the target of the image analysis, and performed using equipment, and setting their significant parameters, to record images with the required characteristics in terms of data typology (e.g. digital images or clouds of points), resolution, etc. Where geo-referencing operations are needed, the data acquisition phase includes markers positioning for a reference system setup.*
2. Image processing *The image processing techniques cover different procedures, including the measurements network adjustment for the reference system definition, if required, the image geo-referencing and the operations necessary to undistort digital images (e.g. minimizing the optical and perspective distortions due to both the optical element used and the perspective visual). Image processing makes the digital images suitable for the interpretation stage.*
3. Information gathering from the automatic/assisted image interpretation *The image analysis procedures aim to gather only the "important" information from the image(s) under exam, through a wide range of algorithms used to prepare images for different purposes (e.g. the identification and count of features in an image, or the evaluation of the radiometric content differences between couples of images) (Russ, 2002).*

Tab. 3. Logical flow of the Image Analysis implementation.
Flusso logico di applicazione delle tecniche di Analisi di Immagine.

duced in the "*asbestos*" subpart of the Guideline.

The techniques provide different improvement levels in the Hazard Identification and Risk Assessment and Management, in particular in the Green and Yellow categorized areas (Table 4).

3.2.1. Global analysis by Light Detection and Ranging – LiDAR

Data acquisition phase of Table 3 – The LiDAR technique can acquire clouds of 3D points, each point containing four information: the three point coordinates X, Y and Z, and the reflectance value. For a realistic view, the cloud of points can be colored with RGB images. The Global analysis is carried out using these clouds of points as input data, still maintaining the quality of information.

Cloud processing phase of Table 3 – Clouds of points are not affected by optical and perspective distortions, making unnecessary preliminary image processing.

Information gathering phase of Table 3 – The information gathering, supported by special software (e.g. CloudCompare ®), derives from accurate superimposing of the clouds of points of the investigated area, recorded in different times. A preliminary adjustment of the position of the markers is required for the comparison of multi-temporal clouds of points.

3.2.2. Image Analysis on high resolution digital images – Local analysis

Data acquisition phase of Table 3 – The acquisition of high-resolution digital images of every ACMs identified for the Local analysis should be carried out keeping unchanged the shooting parameters, in particular the focal length. The markers of the local reference system are necessary for the image processing procedure, namely for the perspective deformation recovery.

Image processing phase of Table 3 – The quality of digital images depends on the quality of the used lens; the image distortions must be adjusted, in particular when pictures are involved in precise measurements processes. Moreover, in the case of accurate images superimposing, the perspective deformations due to the different shooting perspective should be recovered. Preliminarily to the Local analysis, both in radiometric and geometrical approach, a careful Image processing (Russ, 2002) is pivotal both to correct the image distortions through lens calibration, and to recover the perspective deformations, using the equations of the homography.

Information gathering phase of Table 3 – Both *radiometric differences*, and *geometrical* analysis techniques can be implemented to perform the assisted image interpretation. The *radiometric differences* approach performs the comparison of the radiometric content of each couple of corresponding pixels of the images to compare, geo referenced in the same local reference system. The *geometrical analysis* is based on precision measuring operations on the images (e.g. measurements of length, areas or pixels coordinates): a variation of these features between the compared images, covering the part of the object under investigation, can be representative of an alteration of the artefact conditions.

4. Validation of the Image Analysis technique in the frame of the "asbestos" sub-part of the Guideline: test layout and results

Test site details: the Image Analysis approach was tested to verify its effectiveness in the Canvassing of a Yellow classified area, characterized by the presence of an enclosure, near to the ceiling, segregating insulated pipes. In the Hazard Identification/

Modus Operandi	
1. 3D Base model	*3D Base model is the initial acquisition, by means of a laser-scanner technique, of digitalized information on the investigated area, necessary for a detailed high quality "snap-shot", and to fix a permanent reference system for the future acquisitions vs pre-positioned markers (more than one acquisition can be necessary, to include critical points located in blind zones). The initial acquisition can conveniently take place during the Canvassing phase;*
2. Global analysis	*The global analysis, based on the computer aided comparison of the global laser-scanner acquisitions of the same area gathered at different times and geo referenced in the system defined in the 3D Base model, can point out coarse modifications in the area (structural modifications, equipment, furniture etc.);*
3. Local analysis	*The local analysis entails the collection of high-resolution digital images of critical points of particular interest, identified through the documentary analysis and Canvassing investigation. So, the first set of high resolution images should be collected at the end of the Canvassing investigation, as soon as a permanent local reference system is set up. Thanks to the high resolution, it is then possible to point out in detail localized changes in size, conditions and shape of artefacts or sealing/enclosures down to millimetre scale.*

Tab. 4. Modus operandi for the Image Analysis implementation.
Modus operandi per l'implementazione delle tecniche di Analisi di Immagine.

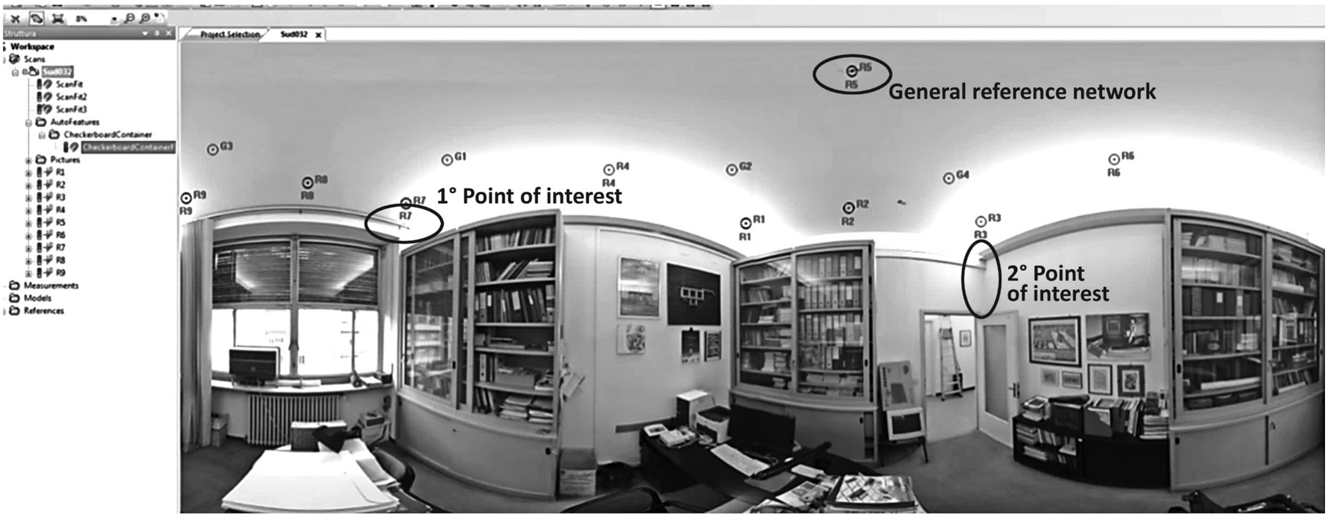


Fig. 1. 3D Base model of the Test area, reference system, and points of interest location.
3D Base model dell'area test, sistema di riferimento, e posizione dei punti di interesse.

in situ surveys phase, the Canvassing made possible the detection, and photographic documentation, of both an ongoing discontinuity (*1° point of interest*) between the enclosure panel and the side walls, potentially invalidating the effectiveness of the enclosure, and a discontinuity on the wall (2° *point of interest*) not directly related with the enclosure, but potentially starting point of further cracks that may involve the enclosure.

Test period and equipment: during the inspections carried out from October 2015 (preliminary inspection on the test area) to April 2017, three sets of high-resolution digital images and LiDAR acquisitions were recorded, using a Nikon D800E high-resolution reflex camera (FF 36 Mpixel), equipped with AF-S NIKKOR 24-70mm f/2.8G ED lens, used with 50 mm fixed focal length, and a CAM2 Focus 3D laser scanner.

The inspections were planned taking into account the window fixtures replacement operations, involving consecutively both the Yellow classified area, and the nearby areas: the removal operations and the mechanical stresses on the identified points of interest represent useful information to interpret the results of the Image Analysis and Local Analysis.

Figure 1 shows a screenshot of the 3D Base model of the tests area.

Data processing for the Global analysis: according to the discussed approach, the first step of the Quality Management of the area is a general analysis performed geo referencing and superimposing the two scans to the 3D Base model. The measurements network adjustment for the reference system definition, with the Least Square method, reduced to 1 mm the maximum uncertainty of the markers position, both in X and Y coordinates, providing an increased accuracy in the superimposing operations (Figure 2).

Data processing for the Local analysis: the Local Analysis tests involved the 2° point of interest:

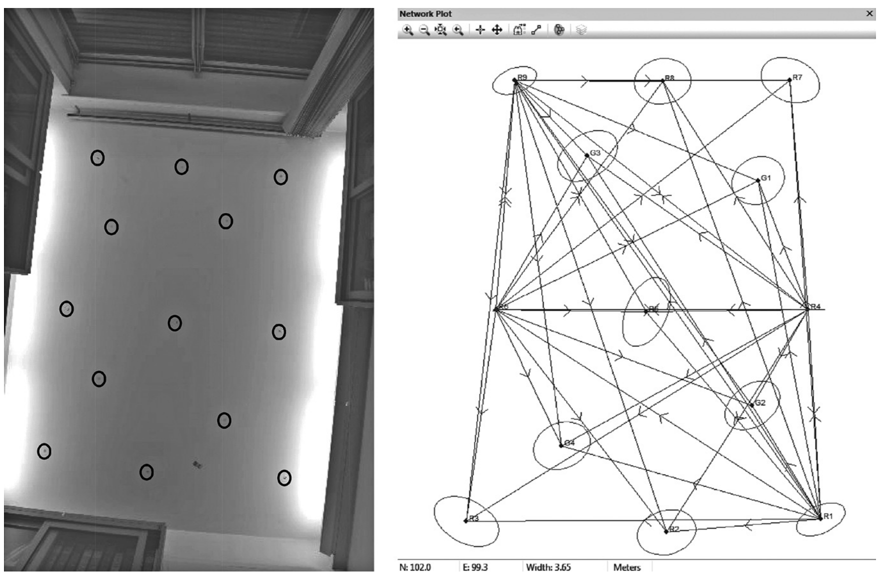


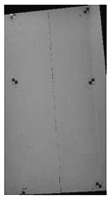
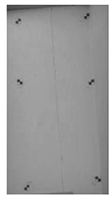
Fig. 2. Reference system – circles evidence the markers (left), Least Square network adjustment with error ellipses (right).
Sistema di riferimento – i cerchi evidenziano i markers (sinistra), compensazione del sistema di riferimento con metodo ai Minimi Quadrati con ellissi d'errore (destra).

the flatness characteristics of the surface where the crack is located simplifies the Image processing procedure.

The three images, selected from the sets of data, show comparable features in terms of geometrical resolution (300 dot per inch – dpi), focal length 50 mm, focal ratio f/4÷f/3. After the preliminary Image processing, and the adjustment of the mutual distances for the local reference system definition, the three images of the crack were analyzed, in two consecutive steps, according to the timeline of images acquisition. Table 5 shows an example of the quoted *Identity Card* of the point of interest, including the three images and related information.

As an example, Figure 3 shows the *difference-image*[2] resulting from the subtraction of image 1 and image 2 with the *radiometric difference method*: the white colored pixels are representative of the wall crack alteration. The object coordinates are available directly on the resulting *difference-image*: thanks to the accuracy in the range of 1 mm of such coordinates, and to the 0,3 mm Ground Sample Distance – GSD resulting from the selected shooting project, it is possible to perform precise measurements on the identified modifications of the discontinuity, according to the *geometrical analysis approach*.

As shown in the right part (result of the analysis in high detail) of Figure 3, zero difference values between the corresponding pixels of the two recorded images result in a black representation, i.e. in no detectable modification of the point of interest in the timespan between the shooting of the two images, whilst the colored parts correspond to un-matching pixels of the input images, and provide evidence of alterations in the point of interest conditions. Direct measurements of modifications in length and width of the crack are also possible.

	Image 1	***Image 2***	***Image 3***
Shooting date	May 5th 2016	December 14th 2016	April 26th 2017
Original file	GEO_0984.JPG	GEO_1289.JPG	GEO_2564.JPG
Adjusted file *(optical and perspective deformations recovered)*	geo_0984_orizz_raddrizz ⇩ 	geo_1289_orizz_raddrizz ⇩ 	geo_2564_raddrizz ⇩ 
Note	Planned window fixtures replacement not yet carried out.	Planned window fixtures replacement completed into the area.	Planned window fixtures replacement completed in nearby areas.

Tab. 5. Identity Card of the point of interest.
Carta d'identità del punto di interesse.

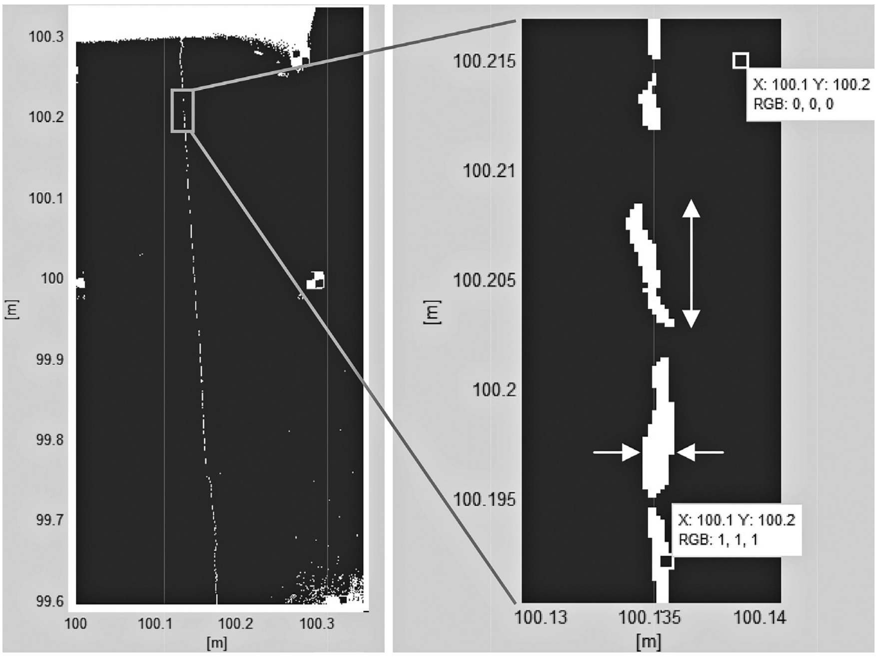


Fig. 3. Radiometric difference-image resulting from the subtraction between image1 and image 2 of the point of interest Identity Card of Tab. 5.
Immagine-differenza risultante della differenza radiometrica tra l'immagine 1 e l'immagine 2 del punto di interesse la cui Carta d'identità è riportata in Tab. 5.

Test results

Global Analysis: No coarse modifications occurred during the time interval between the first and the last acquisition.

Local Analysis: The extent of the white colored area involving the wall discontinuity denotes a significant alteration (most likely imperceptible through a simple visual analysis), occurred between May 2016 and December 2016. The alteration of the crack is measurable (enlargements more than 1 mm measured on the difference image), probably due to structural mechanical stresses during the window fixtures replacement works.

[2] An original Matlab MathWorks® algorithm reading and subtracting two input images generates a matrix of differences, i.e. a "*difference image*"

5. Discussion on the contribution of Image Analysis techniques for effectiveness and quality of the "asbestos" sub-part of the Guideline

The implementation of computer assisted image processing and interpretation techniques into the "*asbestos*" sub-part of the Guideline to support the inspection activities – in particular in Green and Yellow classified areas – provides a documented history of the artefacts conditions along the time, both in small and large scale, the latter making available Identity Cards of the points of interest, and results in substantial improvements in the Quality Management of Occupational Safety in these areas. Table 6 summarizes the main improvements, and the possible future developments of the approach.

Improvements in the Hazard Identification and Risk Assessment and Management made possible by the introduction of Image Analysis techniques for the ACMs status and sealing/enclosures conditions, in Green and Yellow areas.	
The common approach, based on inspectors' subjective judgment, can result in not exhaustive Hazard mode and Risk Assessment, and inspections scheduling.	The introduction of an Image Analysis approach in the "asbestos" sub-part of the Guideline makes possible the following improvements
a) poor completeness, in particular when checklists are used (see comments in the Canvassing chapter);	**a)** *the* ***3D Base model*** *makes available a complete – event if rough– documentation of the Canvassing results in the area; it is moreover possible to implement into the 3D Base model geo referenced information on the positions where ACMs are present;*
b) modifications in the layout of services, systems and interior spaces containing workplaces and working equipment can remain not completely noticed by a coarse inspection;	**b)** *the* ***3D Base model*** *provides an effective tool for the comparison of the general area conditions along the time, both for direct evaluations by the people charged of the inspections, and for more detailed comparisons, supported by computer-assisted image analysis –**Global Analysis**- of the sequence of acquisitions;*
c) poor results in terms of recognition and assessment of changes in the ACMs or sealing/enclosures conditions along the time;	**c)** ***Local Analysis*** *makes possible to directly point out in detail localized changes in size, conditions and shape of ACMs, artefacts or sealing/enclosures: this is of great help to confirm or modify, on a not subjective base, the area classification (in particular from Yellow to Red);*
d) possible -even unacceptable- delay between critical modifications in ACMs or sealing/enclosures status, and the inspections.	**d)** *the use of permanent camera systems (in particular for Local Analysis of critical points of interest) and data loggers can ensure a monitoring of the status of ACMs and sealing/enclosures at predefined intervals and/or on remote demand, and setup in real time alarms where significant modifications occur, independent from the schedule of inspections.*

Tab. 6. Improvements in the Hazard Identification and Risk Assessment and Management made possible by the introduction of Image Analysis techniques in the "asbestos" sub-part of the Guideline.
Miglioramenti nelle fasi di Identificazione dei Fattori di pericolo e Valutazione e Gestione del Rischio apportati tramite l'implementazione di tecniche di Analisi di Immagine nella sottofase "amianto" della Linea Guida.

6. Conclusion

The *"asbestos"* sub-phase of the effective and well tested Guideline for Occupational Safety in Universities and large public facilities, encouraged since 2008 by Politecnico di Torino and Universita' degli Studi di Torino, an officially quoted as basic reference in 2015, results from a multidisciplinary research study aimed to provide a reliable reference for the Assessment and Quality Management of Risk of exposure to air-dispersed respirable asbestos fibers, covering the definition of the correct approaches in scenarios from confirmed absence of ACM, to the various Hazard modes, from Dormant, to Armed, to Active.

As demonstrated by direct in situ tests, the implementation of Image Analysis techniques into the Canvassing recommended approach for a reliable Hazard Identification and asbestos Hazard mode confirmation along the time, is feasible and makes possible substantial improvements in the investigations results, directly in terms of detail, reliability and repeatability, and in general for the overall quality of the investigations and decision making processes.

Such an approach could result also beneficial where implemented in refurbishing works involving civil and industrial buildings, thanks to the possibility to achieve an improved exhaustiveness of the operations, and a documented effectiveness of the intervention performed.

Asides from the direct results here discussed, further developments in the implementation of Image Analysis techniques for the Assessment and Management of Occupational risks nowadays possible will substantially contribute to the transition of OS&H from approaches still conditioned by the subjective judgment of a human observer, or relying on poorly effective techniques, to methods more consistent with the evolution of the production systems towards checks and controls from remote, with high digitalization and automation levels.

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