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editors

D-SITE

Drones - Systems of Information on culTural hEritage. For a spatial and social investigation

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AFTERWORD

SPONSOR

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Keywords:
Rubble survey, rubble analysis, virtual 3 reconstruction, cataloguing procedure, database construction.

ABSTRACT

At the heart of the debate regarding the serious traumatic events that can affect cultural assets is the need for procedures for handling the rubble in order to better manage the reconstruction phase well in advance of construction phase.

The planning and implementation of UAV activities during rubble removal provides a useful support for the reconstruction. The organization of databases that allow data on rubble to be filed not as a simple counts, but instead based on the morphology of its constituent elements, makes it possible to devise a reconstruction plan based on the actual elements recovered.

Post-earthquake rubble management: the potential contribution of UAV for architectural heritage restoration

1. Introduction

There are several phenomena that can have an impact on buildings, particularly historical buildings, resulting in the caving in and/or collapsing of parts of or entire structures. When one looks at the historical series of traumatic events associated with natural phenomena, a noticeable increase in terms of intensity and frequency since the beginning of the last century is evident both locally and globally. While the disasters arising from hydro-meteorological and biological phenomena have grown exponentially due to the sharp increase in risk (climate change), the slight increase in destructive events caused by geological events, particularly earthquakes, is most likely caused by an increase in vulnerability and exposure. Furthermore, in Western Europe, in the second post-war period, traumatic events linked to conflicts or actions of a terroristic or, in any case, criminal nature have had various ups and downs, with a slight recovery in the last two decades.

After such events, whether natural or man-made, it is essential for a complex but accurate debris management system to be consider multiple instances that will set off the operating procedures to be put in place by the structure appointed for the purpose of emergency situations. In Italy, the seismic events of the last ten years (Abruzzo 2009, Emilia 2012 and Central Italy 2016) have slowly led to the definition of specific measures (government Ordinances) and procedures for assessment of outcomes related to the management of collapsed or demolished buildings. In this context, particular attention is being paid to the activation of differentiated procedures for handling rubble from collapsed buildings of cultural interest. However, it has been challenging to apply these procedures in post-earthquake contexts, highlighting the need to study additional strategies that involve the classification of rubble for the purposes of restoration of the site. These must be closely related, not only to the relevance of the destroyed architectural asset, but also to its precise placement before and after the traumatic event (Figure 1). To this end, photographic data from drones, even if acquired for purposes other than those linked to the future reconstruction, can be a useful aid for the subsequent intervention phases.

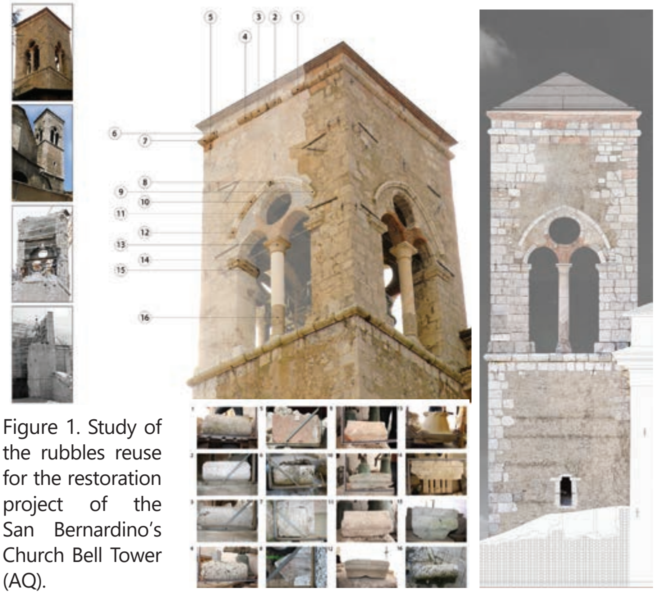

Figure 1. Study of the rubbles reuse for the restoration project of the San Bernardino's Church Bell Tower (AQ).

2. Recovering the rubble-collapse analysis and initial provisions

A collapse causes, on the one hand, the presence of material on the ground and the consequent formation of rubble[1] and, on the other, the presence, of incomplete wall structures, often in a condition of precarious equilibrium, i.e., ruins[2]. The kind of phenomenon that produced the rubble will significantly affect the type of damage that it causes. In the event of an earthquake, for example, the damage is often '*systemic*' affecting usually the entire building, but is manifested with greater or lesser intensity depending on the level of vulnerability of a building or, rather, a the single structural unit in its own context. Furthermore, related to the stresses affecting the wall structure with out-of-plane action, collapse mechanisms of overturning, vertical bending or horizontal bending frequently occur. In Italy, these types of destructive events have led to reflections focusing on how to regulate reconstruction of the ruined architectural elements on the ground or, in any case, displaced with respect to their original position within the framework of the restoration, one of the most interesting topics of debate in the second post-war period[3]. This is not the place to investigate the complex relationship between the quality of the recovery of the collapsed elements and the possibility of recomposing them by completing the missing parts, but when it comes to the importance of the methods used for recovering rubble, the reflections by Alfredo Barbacci appear to be fundamental. In 1956 he underlined how "*the first guide for the re-composition is given by the position of the various elements*"[4]. Subsequently, as a result of the Friulian experience, Alba Bellina, when drafting the analysis sheets of numerous reconstruction interventions carried out in Gemona and Venzone, integrated the reading of the damage suffered and the methods of collapse with analysis of the methods of clearing the rubble, and recovery and cataloguing of stone elements. The aim was to evaluate in a "*scientific*" manner what the author defines as a "*recoverability index*"[5] (Figure 2).

The importance of the rubble removal procedure is reaffirmed strongly by both Alba Bellina and Francesco Doglioni.

They emphasise that the anastylosis intervention should begin as soon as the collapse has occurred, and indicate the "*archaeological method*"[6] as a reference for the removal and sorting of rubble.

According to the two authors, the analysis of the position of the elements on the ground is particularly relevant to the study of how the building collapsed [7](Figure 3). It was not until the end of 2013 that the first regulatory provisions were issued by MiBACT concerning the management of actions to secure and safeguard cultural heritage in the event of emergencies arising from natural disasters[8]. The same Ministry then issued a specific directive on "*Procedures for the removal and recovery of rubble of protected assets and historic buildings*"[9] pertaining to the seismic events recorded from 24th August 2016. This Directive provides for the acquisition of photographs taken from above using drones before and during the removal of the rubble.

Although the case of the Church of Saint Benedict in Norcia (PG) revealed several critical issues regarding

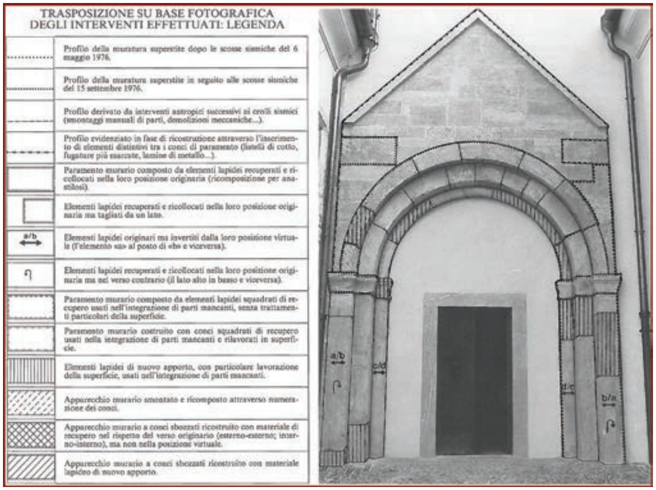

Figure 2. Example of Alba Bellina analysis of reconstruction intervention in Gemona.

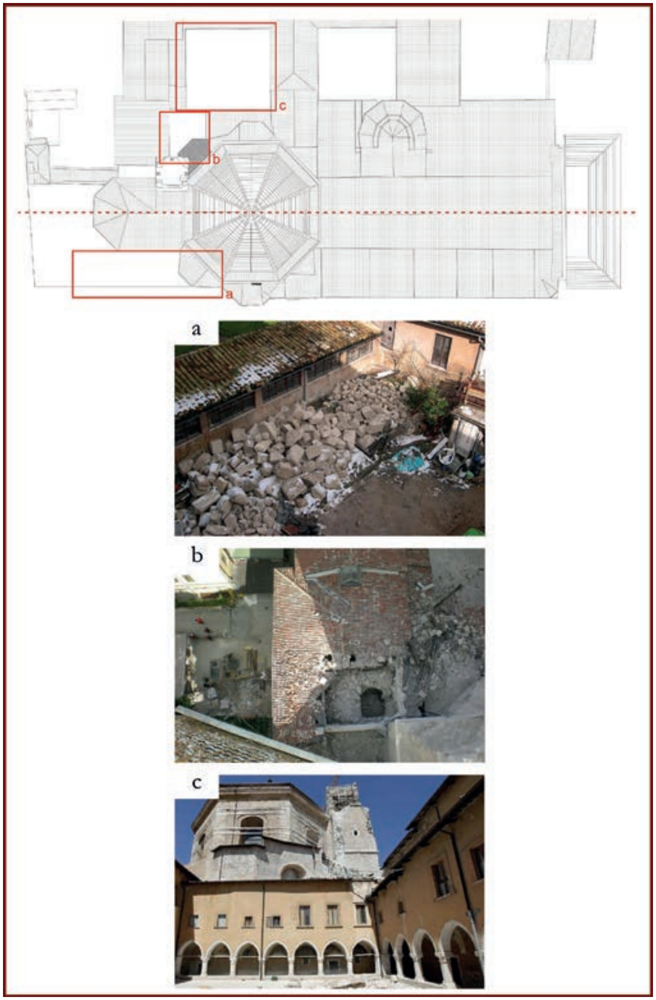

Figure 3. Bell Tower of San Bernardino's Church (AQ): identification of the drop points on ground of the structure.

the application of the ministerial decrees[10], it did provide an opportunity for qualification of the methods of removal and recovery of rubble in the construction site.

Specifically, drones, or UAVs, were used to create an orthophotographic base for the purposes of geo-referencing the removed fragments and documenting the work, considering the impossibility of applying the stratigraphic method for reasons related to the safety of the workers. Though singular situation (few other post-earthquake sites have seen the use of remotely piloted aircraft since 2016), the case of the Church of Saint Benedict highlighted several limitations in the exploitation of the potential offered by these tools, which are widely present on the market today. Retracing the different operational phases that followed the traumatic event allows us to promptly verify the possible strategies of integrating the use of drones. The ultimate aim is the continual improvement of the quality of the recovery of the collapsed elements which, it should be emphasised, cannot constitute the only condition for allowing the same elements to be recomposed.

3. Handling the rubble in the emergency phase

In the immediate aftermath of a collapse event, the immediate action of the authorities is solely aimed at rescuing people involved in the collapses. This type of intervention generally requires delicate manoeuvres, often manual, to excavate and remove debris from the ground. The only factor governing such removal operations is the need for them to be carried out as quickly as possible without causing further harm to any survivors.

Simultaneously, and immediately afterwards, initial work begins on clearing accessibility/connection infrastructure so as to allow an effective throughway between emergency areas and strategic sites (e.g. recovery centres and hospitals). In medium to large cities, these routes may be the oldest roads, normally typified by the presence of important historical buildings, even of a specialised nature. In this case too, the speed necessary for operations of debris removal caused by collapses that often involve such buildings, usually facing the road, does not enable control of what is being moved. Finally, and always under extremely tight deadlines, controlled demolition[11] of buildings or parts of buildings (towers, bell towers, chimneys, slender wall structures that are not near the road, etc.) can be carried out. This can jeopardise the safety of rescue operations and subsequent inspections by experts in order to verify and assess the damage done and by the residents themselves in their own homes. Even though the time required for such interventions should enable the so-called "*controlled dismantling*" of the wall structures, the lack of specialised human resources usually entails decidedly less rigorous procedures (Figure 4 and Figure 5).

During these delicate phases, drones are already being widely used by first responders. Several flights are performed in order to assess the need for rescue interventions aimed at saving people trapped under the remains of the buildings, before continuing with the subsequent phases of removing and/or moving the rubble.

Once the phase of extreme urgency is over, having taken note of the overall damage level, a Legislative Decree is issued.

This establishes how the subsequent emergency phase should be managed, with particular reference to the procedures, at a national level; the institutional players involved; and, above all, the human and economic resources to be deployed.

The player having the greatest influence in the management of the emergency is the Commissioner for the reconstruction, who is appointed by the National Government.

The Commissioner then decrees the actions to be taken via one or more Ordinances[12].

The management of the rubble is generally one of the main subjects outlined in the Legislative Decree[13], but it is dealt with in more precise detail in the subsequent Ordinances.

In this phase, a plan should be created to survey the area using drones, in relation to the activities to be carried out on the ground. The aim should be to be able to put in place data collected in a more or less finalised way that allows the creation of a rough database to be used in the reconstruction.

Figure 4. Palazzo del Governo and Sant Agostino's Church (AQ): in red and in yellow the exemplification how rubbles are moved during the emergency phase.

Figure 5. Church of Sant'Andrea (Campi di Norcia - PG) before and after the earthquake in 2016. The rubbles were moved to allow the vehicle passage.

Drone flights are especially useful when architectural elements have already been removed, without their being associated with their own area of collapse (the aforementioned uncontrolled removal), but also when they have; in the latter case they enable the real roto-translation of each element within the'Stratigraphic Units' to be pinpointed.

4. Information managment

4.1 Removal of rubble – land and air activities

To analyse the collapse and plan the reconstruction, we must be able to relate each element removed (to be surveyed via photogrammetry later on) with the portion of the building that it originated from, and to refer them to their respective collapse mechanisms (Figure 6). The activities required should take place according to a logical sequence that involves alternating drone flights with rubble removal on the ground.

This allows us to obtain frames for each'Stratigraphic Unit' being monitored (Figure 7). Each sequential "*macro-phase*" (drone flight + rubble layer removal), carried out in a consequential manner, has the aim of surveying, through photogrammetry, the architectural elements in the context of the collapse.

The large number of elements to be surveyed, as well as the compulsory expeditious nature of the operations, means that the metric references required for the post-processing phases need to be carefully planned and prepared; it is also necessary to conduct accurate and timely classification and indexing of the frames.

This will enable a reading of the frames that will be "*linear*" (i.e. in chronological order) but, above all, "*closed*" (i.e. with frames associated with their respective areas of collapse).

4.2 Creation of the database

The time interval between the removal phase and the processing of the data (years, even in the best-case scenario) makes necessary to begin work on database construction during the first phases.

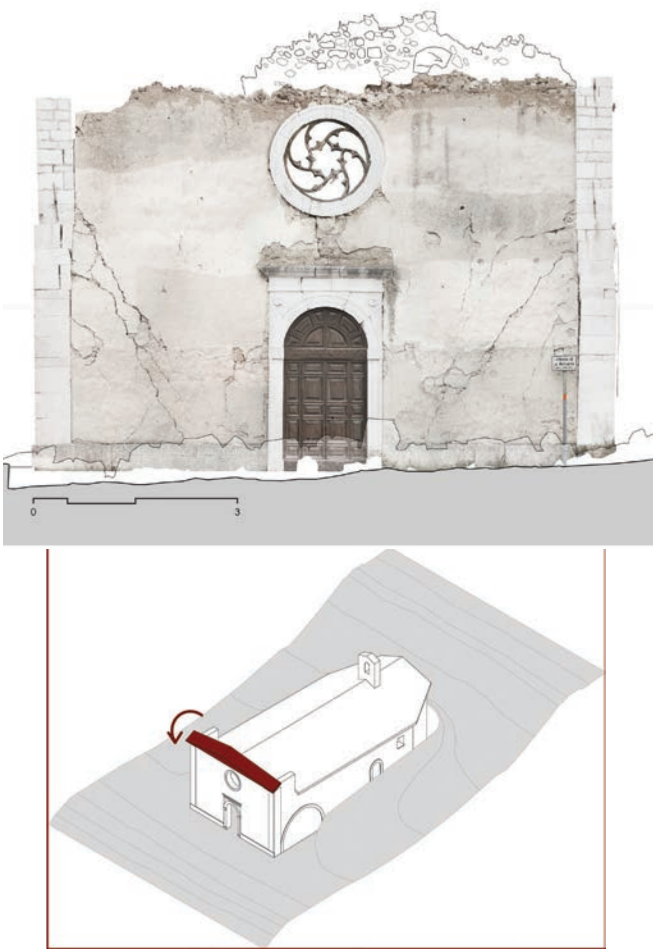

Figure 6. Identification of the collapse mechanisms that generate the presence of rubbles in front of the façade of Sant'Andrea Church. (Credit: M. Agnelliti, M. Venturoli Gabriel)

This initial database - Database 0 - must be able to be eventually implemented and as such it should contain the following information:

- Drone images and footage taken during the emergency phases.
- Flights performed during the emergency phase enable the positions of the architectural elements in the immediate aftermath of the collapse to be

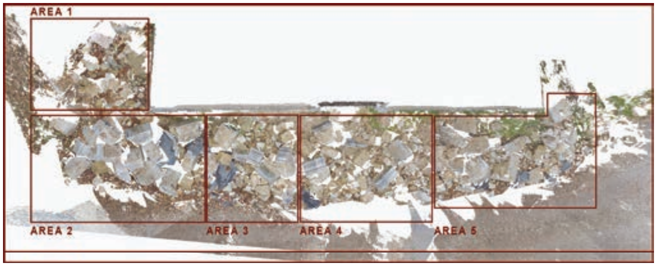

Figure 7. Planning of the Stratigraphic Units for the rubbles survey of Sant'Andrea Church.

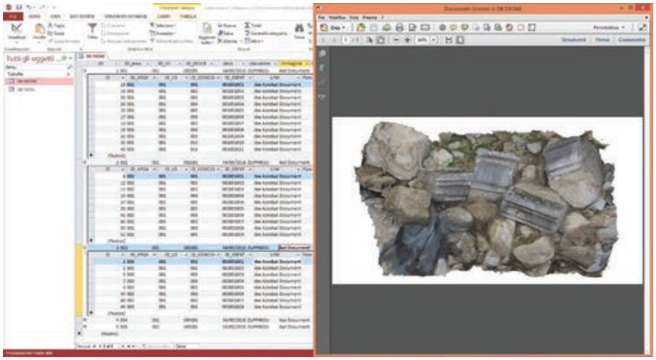

Figure 8. Sant'Andrea database 1: the database contains elaboration of the point cloud per each area of collapse planned.

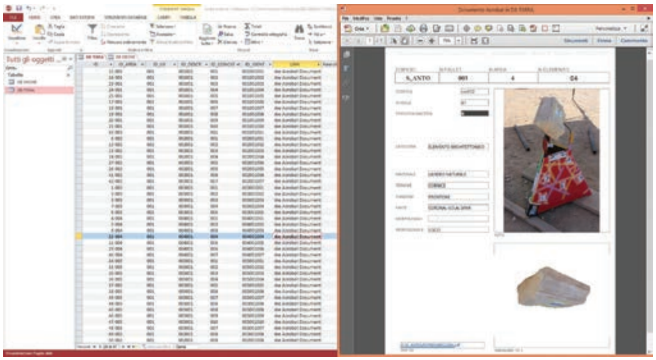

Figure 9. Sant'Andrea database 2: the database contains the catalogue of each elements surveyed on ground.

identified, and the movement of the rubble to be "mapped". These positions will be different from those surveyed later on, and drone footage thereby makes it possible to trace back the various phases of rubble movement and to identify the real points of collapse of the displaced elements.

- Drone footage frames taken during the rubble removal phases.
- These will be useful for photogrammetric survey of the rubble in the extraction phase (phase 4.1).
- Images of architectural elements taken from the ground for the photogrammetric survey of the single elements[14].
- Two different databases will be created later on. One, Database 1, will contain the point cloud of each area of collapse (drone photogrammetry) (Figure 8), while the other, Database 2, will be completed with the point cloud pertaining to each element (on-ground photogrammetry) (Figure 9).

Other useful sources of information that could add to to the data are:

- Laser scanner survey of the post-earthquake state (Figure 10). The laser scanner survey is useful both for a more accurate metric reference of the rubble pile (software able to process together photogrammetry and point clouds from a laser scanner), and to refer the elements on ground with their exact position within the monumental building (the metric accuracy of laser scanner survey allows more precise correlation with the features still present in the building).
- Surveys of the pre-earthquake state (if available).
- Historical photographic documentation.

4.3 Database Correlation

The next stage is to link up the two databases in order to correlate the various elements catalogued in Database 2 with the data contained in Database 1, which records the morphology of each element in the '*Stratigraphic Units*' (Figure 11). Correlating the two databases makes it possible to:

Figure 10. Laser scanner point cloud of Sant'Andrea Church.

- Identify the area of collapse (Database 1) for each of the surveyed elements (Database 2), data which is never included in the documentation pertaining to uncontrolled removal.
- Establish the roto-translational movements of the elements during the collapse, information which helps us to better understand collapse mechanisms.
- Recognise the pre-earthquake positions of similar and consecutive elements.

The use of comparable elements which compose architectural features (cornice, architrave etc.) does not permit the univocal re-collocation of the elements through identification of the number of area they belong to alone.

To define the correct position of each element belonging to a set of similar elements within the area of collapse, correlation of the elements in Database 2 with the information in Database 1 is required (Figure 12). Other information that may be useful are the lithotype, surface treatment, and state of decay, amongst other factors.

4.4 Virtual reconstruction

The above procedure became a starting point for the virtual reconstruction (Figure 13) of the collapsed architectural elements on the ground[15].

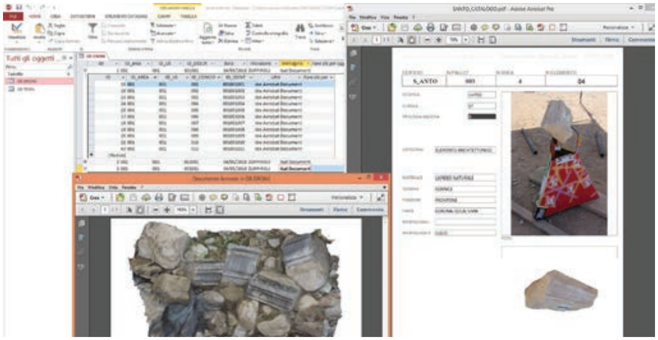

Figure 11. Correlation of database 1 and 2 of Sant'Andrea Church. Each component of database 2 is related to its own area in database 1. The correlation was realised manually by the operator recognising the morphology, the degradation and other aspects.

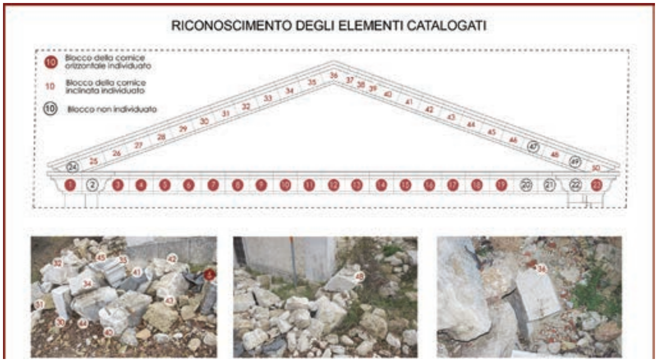

Figure 12. Example of correct positioning of each elements belonging to a set of similar elements for the cornice of Sant'Andrea Church. (Credit: M. Agnelliti, M. Venturoli Gabriel).

5. Conclusion

The different aforementioned uses of the drone's images during the removal and cataloguing procedure underline the needs on the one hand to improve drone flights, especially in the emergency phase, the phase in which the rubble has not yet been moved, and on the other to coordinate and plan the activity on the ground with the UAV.

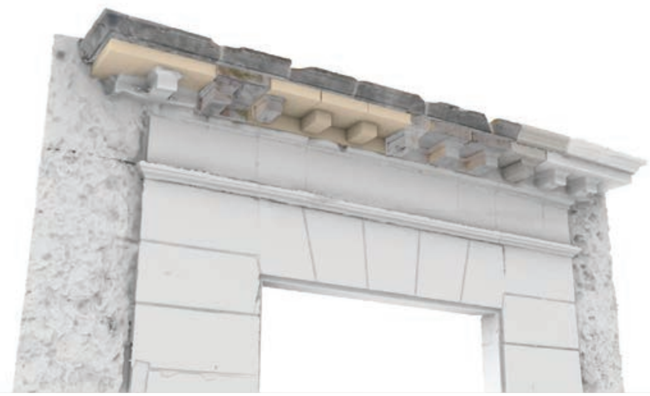

Figure 13. The virtual re-collocation of the elements recognised in the rubbles of Palazzo del Governo (AQ). The different colours identify the elements still in situ, the elements virtually re-located and elements definitely lost which are represented through simplified forms.

Secondly, the creation of a photographic database (Database 0), structured according to space and time ("*closed*" and "*linear*" reading of the frame, as shown in in 4.1), enables construction of Database 1 and Database 2 to be postponed until requirements related to the restoration and/or reconstruction project arise. As additional consideration, the databases correlation expressed in point 4.3 is currently carried out by a human operator, who manually identifies and connects the different databases elements; in the future this process will likely be automated thanks to the implementation of software based on AI and neural networks.

NOTE

1 The Italian term "maceria" (meaning rubble) seems to refer to the Greek noun "makaria" meaning "flour dough and broth". Therefore, it does not seem related to the type of material but rather to the chaotic way in which it is destroyed and to the fact that it is impossible to distinguish its constituent elements.

2 The term "ruin" comes from the Latin "*rŭīna*" and means both the material that falls to the ground and the remains and surviving structures of buildings and urban complexes that have suffered partial or total collapse. The term is often used in connection with the parts of ancient buildings that are still standing. In the context of this report, we use it in its general meaning.

3 For more information on this theme, with particular attention to the second post-war period, see M. P. I. *Direzione Generale delle Antichità e Belle Arti*, 1950, pp. 47-48; De Angelis d'Ossat G. 1957, passim; Bonelli R. 1953, pp. 54-58; Barbacci A. 1956, pp. 97-101; Brandi C. 2005, pp. 150-179; Bellina A. 1988, in particular chapter 1 "*L'anastilosi nell'ambito della teoria e storia del restauro*", pp. 19-38; Dalla Negra R. 2012.

4 See Barbacci A. 1956, p. 98. As example he provides two specific cases: "*collapsed portico rovesciato will present itself, even with some reciprocal movement of stones, as a projection of the untouched work on the ground [...] and it will be possible to identify each column with its own capital and base, the arches or the lintel of the subsequent spans, crowning cornices, etc. Similarly, in a fallen wall, the different horizontal rows and the moulding will be identifiable from the position of stones overlapping it, albeit with inevitable uncertainty, especially if they are small elements*" (Translated by the author).

5 Translation of the author from Bellina A. 1988, p. 47.

6 See Bellina A. 1988, in particular "Final notes, by Alba Bellina and Francesco Doglioni" pp. 209-214. (Translated by the author).

7 Ibid, p. 211.

8 Directive of 12th December 2013: Directive of 12th December 2013: "Procedures for management of safety and safeguarding of heritage in the event of emergencies and natural disasters." (GU Serie Generale n. 75 dated 31/3/2014, revised by the Directive dated 23rd April 2015) (Translated by the author).

9 Carried out by the Preservation and Restoration Institute (ISCR) - architect Gisella Capponi, and General Directorate for the Archeology, Fine Arts and Landscape, (DG-ABAP) - Caterina Bon Valsassina and architect Alessandra Marino. (Translated by the author).

10 See Argenti S. et al.. 2017.

11 For example, the demolition of the bell towers at Poggio Renatico (with the use of explosives) and Buonacompra, of the chimney at Bondeno and the Parisio mill in Bologna are mentioned in the context of the 2012 Emilia earthquake.

12 Ordinances by the delegated Commissioner are governed by art. 5, paragraph 2 and 2 bis of Italian Law n. 225' Establishment of the National Civil Protection Service', dated 24th February 1992, and fall into the category of contingent and urgent measures; they may

derogate the laws in force (in compliance with the general principles of the system) and do not have pre-established content.

13 For the 2009 Abruzzo earthquake, please refer to Legislative Decree n. 39 dated 28th April 2009, "Urgent measures for communities affected by earthquake in the Abruzzo region on April 6, 2009 and other urgent operations of civil protection" (Translated by the author), which was converted into Law n. 77 on 24th June 2009, with specific reference to Art.

14 A procedure for the management of the rubble is illustrated in Zuppiroli M. 2019 (part 4).

15 See Zuppiroli M. 2019 (part 4-5).

Bibliography

Argenti S., Betori A., Corrado M. E., Crova C., Fazio M. G. (2017). *La rimozione delle macerie nel post-terremoto. L'approccio propedeutico alla fase della conservazione e del restauro dell'edilizia storica e del patrimonio culturale.* Biscontin G., Driussi G. (edited by) *Le nuove frontiere del restauro. Trasferimenti, Contaminazioni, Ibridazioni.* XXXIII° Convegno Internazionale Scienza e Beni Culturali. (Bressanone, 27-30 giugno 2017). Venezia: Edizioni Arcadia Ricerche, 2017, pp. 375-388.

Barbacci A. (1956). *Il restauro dei monumenti in Italia. Roma: Istituto Poligrafico dello Stato*. Libreria dello Stato.

Brandi C. (2005). *Il restauro. Teoria e Pratica. 1939-1986. Edited by Cordaro M.* Roma: Editori Riuniti.

Bellina A. (1988). *L'anastilosi nella ricostruzione del Friuli. Limiti e modi del restauro per anastilosi in alcune applicazioni a Gemona e Venzone dopo il sisma del 1976.* Udine: Editori Riuniti.

Bonelli R. (1953). *Danni di guerra, ricostruzione dei monumenti e revisione della teoria del restauro architettonico*. Bonelli R. (edited by) *Architettura e restauro.* Venezia: Neri Pozza Editore, 1959, pp. 41-58.

Dalla Negra R. (2012). *Eventi eccezionali e principi conservativi: il terremoto emiliano. Materiali e strutture. Problemi di conservazione*, year 1, vol. 1-2, 2012, pp. 29-41.

De Angelis d'Ossat G. (1957). *Danni di guerra e restauro dei monumenti. In Centro Studi per la Storia dell'Architettura (Roma). Atti del V Convegno nazionale di storia dell'architettura*: Perugia, 23 settembre, 1948. Firenze: Noccioli, 1957, pp. 13-28.

Ministery of Public Education. General Directorates of Antiquity and Fine Arts (1950). *La ricostruzione del patrimonio artistico italiano.* Roma: Libreria dello Stato.

Zuppiroli M. (2019). *Eventi traumatici e gestione delle macerie: indicazioni operative per il patrimonio culturale costruito.* Conte A., Guida A. (edited by) *ReUSO Matera. Patrimonio in divenire. Conoscere, valorizzare, abitare.* Roma: Gangemi, 2019, pp. 2271-2282.

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