Available online at www.sciencedirect.com

ScienceDirect

Procedia Structural Integrity 44 (2023) 275–282

Structural Integrity Procedia

www.elsevier.com/locate/procedia

XIX ANIDIS Conference, Seismic Engineering in Italy

Securing the church of Madonna del Sole during the emergency phase of 2016 earthquake: interoperability of different actors as an instrument for reducing seismic risk of damaged built heritage

Enrica Brusa[a,*], Claudio Chesi[b], Stefano Della Torre[b]

[a] *Politecnico di Milano – Dept. of Architecture and Urban Studies (D.A.St.U.), via Bonardi 3, Milano 20133, Italy*
[b] *Politecnico di Milano – Dept. of Architecture, Built Environment and Construction Engineering (D.A.B.C.), via Ponzio 31, Milano 20133, Italy*

Abstract

Potential damage from seismic risk is particularly high for historic buildings, as it can produce an irreversible loss of value and sense, not only concerning the material meaning but also the intangible one. Undoubtedly, the best strategy to reduce seismic risk of the built heritage consists in assessing and reducing vulnerability. In any case, it is not always possible to early intervene on historic buildings to improve seismic performance, neither it is possible to change or to completely remove some external factors (i.e., the hazard exposure due to local geotechnical features), nor to avoid that aftershocks increase the damage produced by the first event. On the contrary, it is possible to reduce the level of seismic risk for buildings also resorting to the coping capacity of a society, improving the effective reaction that authorities can oppose to a hazardous event, such as an earthquake, already during the emergency phase. This capacity, or preparedness to risk, applies also to the protection of damaged cultural heritage and particularly to churches, which constitute one of the most vulnerable typologies of historic buildings, due mainly to their shape and constructive characteristics.

Recent seismic events have clearly shown that during the emergency phase which immediately follows an earthquake it is still possible to intervene on historic buildings, in order to limit the progress of damage. During a seismic emergency the protection of Cultural Heritage is in charge to public Agencies: the cooperation among them plays an essential role, as well as does the knowledge both of the buildings and of their vulnerability, or the technical ability to properly intervene in order to stop the progress of damage.

This paper shows how interoperability in preparedness to risk can be effectively developed among the different actors involved in the protection of cultural heritage during the post-earthquake emergency phase. The study refers to the case of the church of "Madonna del Sole" in Capodacqua (AP), a hamlet in the heart of the Sibillini Mountains. This case study well demonstrates the importance of preparedness to risk, since a prompt reaction can effectively reduce negative consequences on the built heritage; at the same time, it shows the benefit of achieving a good interoperability of all the actors involved in the protection of cultural heritage during the emergency phase, as they can significatively increase the residual safety of damaged historic buildings.

* Corresponding author.
E-mail address: enrica.brusa@polimi.it

2452-3216
10.1016/j.prostr.2023.01.036

Keywords: cultural heritage; seismic damage; preparedness to risk; interoperability; emergency phase.

Nomenclature

A-DC	A - Damage to Churches	NFB	National Fire Brigade
CdR	Carta del Rischio	NIS	Nucleus for Special Intervention
CP	Civil Protection	RECS	U. for Expert Recognition & Strategic Characterization
GTS	Groups for the Technical Support	SAF	Cave-Alpine-River rescue teams
ICR	Central Institute for Restoration	STCS	Short-Term Contermeasures System
INGV	National Institute of Geophysics and Vulcanology	UAMA	Unit for Supplying Materials and Means
MiBACT	Ministry of Cultural Heritage, Activities and Tourism	UCCN	Crisis Unit for the National Coordination
MiC	Ministry of Culture (before 2021: MiBACT)	UCCR	Crisis Unit for the Regional Coordination

1. Introduction

A critical issue affecting the built heritage in areas with high seismic risk comes from intrinsic vulnerability conditions due to several factors: the building geometric characteristics, the material properties, their state of conservation and the presence of elements of historic and artistic value. As it is well known, vulnerability represents one of the basic parameters in the evaluation of the seismic risk level for a building, together with the 'hazard exposure' (Cacace 2019). Thus, decreasing the vulnerability of an historic building can be an effective solution to reduce the expected damage caused by an earthquake.

In recent years, different tools have been developed for the evaluation of both priority and typology of the necessary interventions, such as the Italian Guidelines of 2011 (DPCM 2011) or the informative system of the "Carta del Rischio" (Risk chart). This system was developed by ICR starting from the 90's and it was then implemented through the years, allowing for a precise identification of locations where cultural heritage subjected to high seismic risk levels can be found (Accardo et al. 2005; Negri 2014), also showing which buildings primarily need interventions (Acierno et al. 2014). Nevertheless, despite the availability of effective tools, it is not often possible to intervene on the historic buildings, mainly due to economic reasons (Della Torre and Borgarino 2014). In this case, an earthquake will probably produce damage and, if some aftershocks will occur, the most vulnerable historic buildings can collapse, as it happened during the seismic sequence occurred in Central Italy in 2016.

1.1. Main parameters for the reduction of seismic risk

The capability to promptly intervene for securing a building damaged by an earthquake is really important to avoid further damage or collapses. This capability is described in the international literature as 'coping capacity', i.e., 'the ability of a system to face a disaster/negative event'; it also represents one of the elements in the definition of seismic risk, according to the equation (Ranke 2015):

$$Risk = Hazard\ exposure \times Vulnerability : Coping\ capacity.$$

The formula shows that it is possible to reduce an expected risk minimizing 'Hazard exposure' and/or 'Vulnerability', or also increasing the level of the 'Coping capacity' of a system. Concerning the seismic risk, the third parameter, also known as 'Preparedness', relates to all the activities and to the knowledge that need to be achieved before an earthquake, in order to proper manage the emergency phase that follows the event. Thus, being related also to the time that precedes an emergency, it concerns also the phase of prevention, and it can correctly be defined as 'Preparedness to risk'.

2. The earthquake of Central Italy (2016) and the first period of the seismic emergency

The importance of achieving this kind of preparedness, in order to reduce seismic risk, became clear during the seismic emergency that interested Central Italy in 2016, when several earthquakes with a high magnitude happened

just a few months one from each other, between 24th August 2016 and 18th January 2017. During that period, 8 earthquakes with a magnitude Mw > 5.0 occurred. The seismic sequence of Central Italy affected an area of about 8000 km^2 (INGV 2022) in the Appennines, between the Laga and the Sibillini mountains, within four different Regions: Lazio, Umbria, Marche, Abruzzo (Chiaraluce et al. 2017; Rossi et al. 2019).

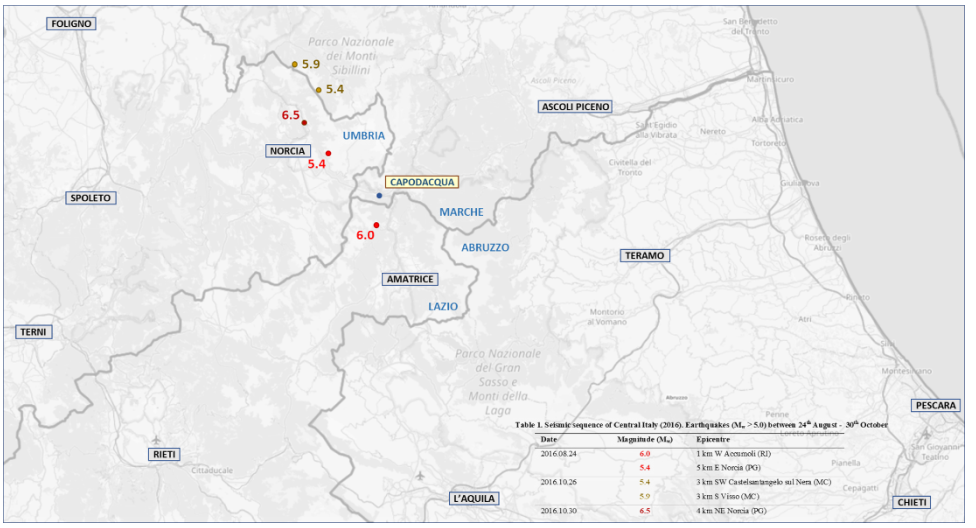

Fig. 1. Earthquakes with a magnitude Mw > 5.0 occurred in the first two months of the emergency phase (2016.08.24 – 2016.10.30)

During the seismic emergency of 2016, the presence of some aftershocks with a magnitude similar to that of the first event has clearly shown the urgence to install technical contermeasures for securing the damaged built heritage, in order to avoid further collapses. Unfortunately, in 2016 most of the damaged historic buildings had not yet been secured two months after the earthquake of August, so that the shocks occurred in October provoked further irreversible losses to the buildings (Parisi, Chesi et al. 2018; Podestà and Scandolo 2017).

After the first rescue activities and the assistance to the population, the CP and the NFB teams, together with the Army and other public Agencies in charge of developing the emergency operations, started to realize the first securing interventions. The first contermeasures are generally installed in the strategic areas, such as the main public roads or public buildings, aiming to reduce the risk for the public safety and to recover the public activities (Brusa 2021). After these first operations, other interventions are performed, based on both the local availability of specialized technicians, means and materials, and on the existing knowledge of the vulnerability of buildings. For these reasons, the damaged built heritage doesn't represent generally one of the priorities for the interventions (Brusa, Chesi and Della Torre 2022).

2.1. The management of the seismic emergency for the built heritage: specialized teams and operative units

When a seismic emergency occurs, the Italian Ministry of Culture activates some special operative units, called UCCR, that work in the affected Regions under the coordination of a National Unit, called UCCN (MiBACT 2015a). These teams verify the level of the damage occurred to the cultural heritage, manage both transport and restoration of mobile artworks to the temporary warehouses and securing interventions for listed buildings. They also help the NFB in designing the technical contermeasures, in order to guarantee the main conservation needs.

The first systematic technical interventions carried out by the NFB for securing the damaged built heritage date back to 1997, during the emergency phase following the Umbria-Marche earthquake. At that time, the SAF teams of the NFB were employed to install the technical contermeasures on the damaged towers and belfries (Cavriani 2014). Other important experiences had taken place during the seismic emergencies of 2002 and 2009, that hit Molise and Abruzzo regions. After these experiences, the NFB and the CP published a manual and a series of technical sheets with guidelines for the design of securing interventions (Grimaz, Barazza et al. 2010; Grimaz, Cavriani et al. 2010). These texts provide the main criteria for the design of technical contermeasures on the basis of the dimension of the damaged

buildings and of the characteristics of the site, always keeping safety conditions for the involved technicians. Proposed technical contermeasures are in line with already existing typologies (Mastrodicasa 2020, Bellizzi 2004), providing special attention to the use of modular elements that can be easily found on the market and stored in warehouses (Caciolai et al. 2013).

Concerning the securing of the built heritage, the technical contermeasures are installed by some specialized teams of the NFB, called NIS. These teams are part of the operative system STCS, that is dedicated to the realization of the emergency intervention. It was created mainly after the emergency experiences of L'Aquila in 2009 and of the Emilia-Romagna and Lombardy in 2012 (Grimaz et al. 2018). The STCS system is composed by three operative units called RECS, NIS and UAMA, that respectively perform the systematic surveys in the areas affected by a disaster, design the technical contermeasures and manage the storage of both materials and means for the intervention.

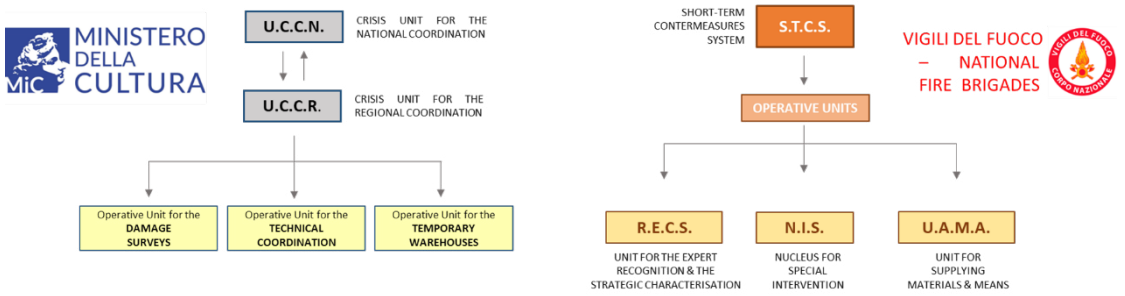

Fig. 2. Emergency Operative Units activated by the Mi.C. and by the N.F.B.

2.2. Warning the damage for the built heritage: criteria for survey and intervention

The choice of the buildings that need to be secured normally happens after the notification of the officiers of the MiC or after an alert from the technicians of the affected municipalities, i.e., when the building has suffered a heavy damage or it threats public safety.

The UCCR teams verify the damage occurred to the buildings through some surveys carried out on the affected sites together with the NFB (MiBACT 2015b). On the other side, a municipality can ask to the public emergency authorities to do a survey for verifying the presence of a danger. This technical surveys, called GTS surveys, are performed together with the technicians of the administration, of the NFB, of the CP and, when the damaged building belongs to the cultural heritage, also together with some members of the MiC or the UCCR. They started in 2016, aiming to rapidly assess the damage and the necessary intervention with the support of interdisciplinary teams (SogAt VvF 2016). Thus, being performed on the basis of a first visual alert, the GTS surveys follow a criterion that is directly related to the urgency of the emergency, also permitting to realize the subsequent intervention in a prompt manner.

3. The church of Madonna del Sole in Capodacqua of Arquata del Tronto (AP)

The church called 'Madonna del Sole' is in Capodacqua, an hamlet of the municipality of Arquata del Tronto that stands beneath the Sibillini mountains in the province of Ascoli Piceno. The hamlet is not far from the border between Lazio, Marche and Umbria, very close to the epicenters of the earthquakes of August and October 2016, happened in the towns of Accumoli (RI), Norcia (PG), Castelsantangelo sul Nera and Visso (MC), as it is shown in Fig. 1.

The church is a small building with a central octagonal plan, whose origin is traced around the first decades of the XVI cent. Its external walls are covered with sandstone blocks and plaster, with a sculpted basement and a moulded string course all along them. Some frescoes representing Christ and the Saints are painted inside, probabily by Cola dell'Amatrice or by some of his disciples. In a niche above the entrance a painting shows Maria surrounded by sunrays, while other decorations and an inscription dated back to 1550 are sculpted near the doors of the church (Fabiani 1952). The church had been recognized of great historic and artistic interest already in 1918, after the promulgation of the Italian law n. 364/1909, one of the first national laws for the conservation of cultural heritage (ICCD 2022, ViR 2021).

When the earthquake of 24th August 2016 occurred, some works for the restoration of the frescoes was in progress. This circumstance made the church well known not only to the local population, but also to the local officiers of MiC.

Fig. 3. (a) Church of 'Madonna del Sole'; (b) The painting showing Maria in the sunrays; (c) Some of the frescoes inside the church.

3.1. The seismic emergency of 2016: first activities and contermeasures carried out in the church

On 9th September 2016, a few days after the earthquake of 24th August, the officiers of the UCCR-Marche did a first survey in Capodacqua, aiming to verify the condition of the church. During this survey the officiers filled a form specifically prepared by the UCCR for the rapid assessment of the damage. This allowed to obtain the necessary information for deciding to take a second detailed survey together with the technicians of the NFB and other experts.

Thus, further surveys for assessing more precisely the occurred damage were carried out on 13th and 19th September by the technicians of the UCCR, while two GTS surveys were done on 19th September and on 04th October, with some representatives of the NFB and the CP, of the municipality of Arquata del Tronto, of the Marche Region and of the MiC–UCCR.

According to the urgency of the emergency, the GTS forms were filled sintetically, aiming to mainly define the typologies of the technical contermeasures and the specific requirements for the worksite. The intervention was realized primarily for protecting the frescoes and avoiding the possible collapse of some parts of the walls of the church on the street, that will have interrupted the public access to the hamlet.

The project of the technical contermeasures was designed within 10th October by one of the team NIS of the NFB, according to the guidelines set out in the STOP manual and it has been approved by MiC on 13th October. It aimed to strongly consolidate the whole structure in three weeks, following 5 different phases of intervention with a team composed by 9 specialized firemen. Firstly, the technicians strengthened the portion of the external wall above the main entrance that had collapsed, reinforcing them with a structure made by wooden 'honeycomb' elements. Then, the NFB realized the reinforcement of the vault with a 'tube and coupler' structure that can easily be adapted to the shape of the inner walls. The anchorage of the metal elements was realized under the supervision of an architect of the UCCR, protecting the frescoes with foam rubber and wooden planks. After having installed this provisional systems, all the openings have been framed with wooden elements and the hooping of the external walls of the church have been installed using wooden planks, polyester stripes and steel cables. The last phase of the securing intervention should had strengthened the sacristy, using 'honeycomb' elements and polyester stripes.

At the end of October, the intervention was not yet completed, also if it had been finished in its main phases: the strengthening of the vaults and of the openings had been completed, while the hooping of the walls and the reinforcement of the sacristy still had to be accomplished.

The realized contermeasures effectively increased the residual strength of the structure, minimizing the occurrence of further collapses to the already damaged parts. On the contrary, some collapses occurred where the contermeasures were not still installed, such as it happened for the bell tower of the church, that collapsed on the sacristy, also damaging part of the roof of the church

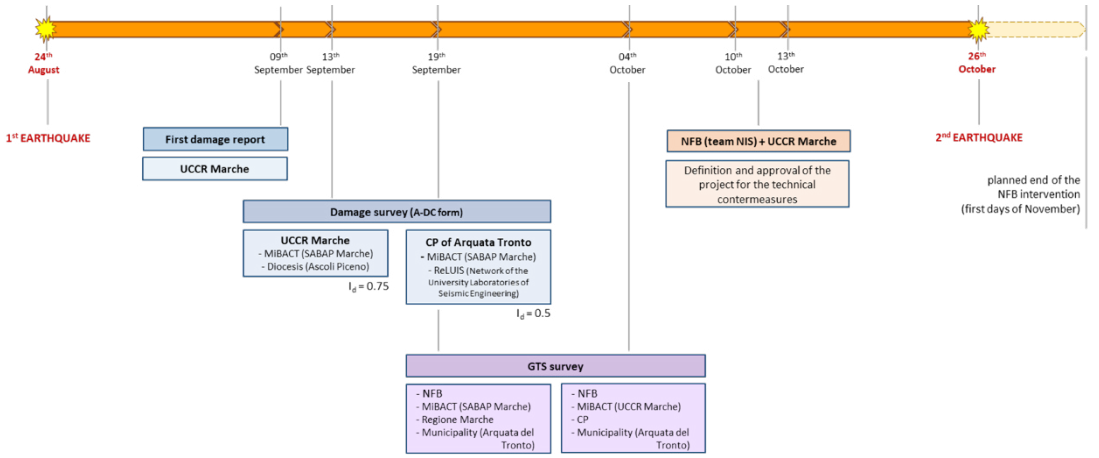

Fig. 4 Diagram of activities and intervention that were provided for the church during the first two months of the emergency.

After the earthquakes of 26th and 30th October 2016, the church was subjected to a further securing intervention, as the existing contermeasures had been seriously damaged, being thus no more able to protect the building. This second intervention was designed in November and it was approved by the MiC at the beginning of December 2016. Nevertheless, it was possible to realize it only during the spring, as the collapse of most of the surrounding buildings made the access to the site very difficult. Furthermore, the big amount of the debris caused some problems for the recognition of the ones belonging to the church, that needed to be stored in a safe place for their restoration, as it was established by the MiC (MiBACT 2016). At the present, the church is still under restoration.

4. Discussion

The case study of the church of 'Madonna del Sole' presents some aspects that need a further reflection: above all, it demonstrates the importance of promptly realize the technical contermeasures for securing the built heritage damaged by an earthquake. This kind of provisional systems are able to minimize further damage provoked by the aftershocks that can follow the first event, thus avoiding further irreversible material losses in the historic buildings.

The case study has also shown the necessity to reach a good interoperability among the technicians and the public officiers that are involved in both the surveys and the intervention: having reached this condition has positively influenced the realization of the emergency activities. Indeed, it has provided a prompt reaction and a successful coordination of the field operations, concerning both the surveys, that were started and performed rapidly, and the presence of different experts from all the involved public Agencies. This interoperability was assured also during the design and the execution of the technical intervention, thus ensuring the respect of the exigences of both the conservation of the historic buildings and the safety of operators through a continuous dialogue among the technicians.

Some improvements can still be realized concerning the scheduling of the surveys carried out by the UCCR, trying to guarantee the presence of experts not only of the architectural field, but also of the engineering one. However, the high number of the surveys that were performed to assess the damage occurred in the church of 'Madonna del Sole' showed a well organization, highlighting also the capability to promptly reschedule the surveys. The use of some synthetic forms, such as the ones employed for the first UCCR survey or for the GTS ones, proved to be effective tools, able to give some useful information also for the following damage surveys carried out filling the A-DC forms, and for the design of the necessary technical contermeasures.

Another significant element is then the opportunity to proceed to the systematization of the available existing data that concern the listed buildings. The knowledge of that infos, related for instance to the building materials or to the restoration works that were realized after previous earthquakes, constitutes an important reference to understand the behaviour of the structure and to design properly the necessary technical contermeasures. Regarding this, a further effort still has to be carried out by the MiC and by the other public Institutes that are in charge of the protection of the Italian built heritage, increasing the available knowledge on the buildings that stand in seismic areas and developing the vulnerability analysis for them, also updating the informative systems such as the "Carta del Rischio", whose data

are still not completed. A specific analysis of the documents that are kept in the public Archives should at least be performed, digitalizing both papers and drawings and copying them in the databases of the local offices of the Ministry. Therefore, the available knowledge could be immediately accessible also during an emergency, when there is not the time to research the data inside the Archives.

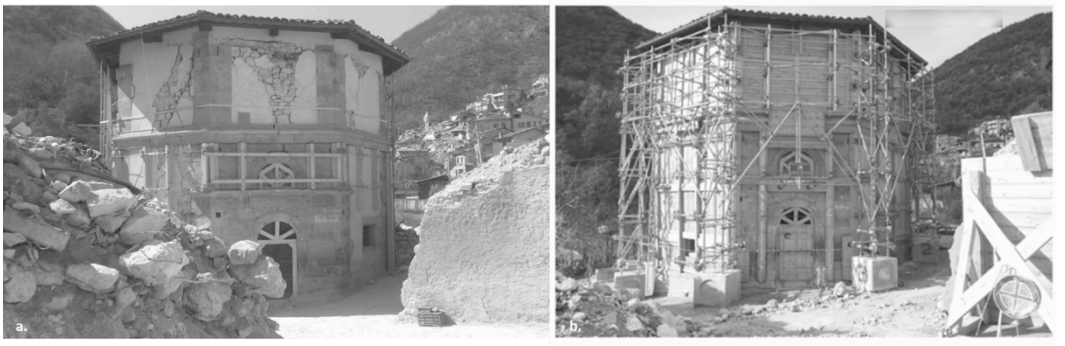

Fig. 5. (a) The church of 'Madonna del Sole' after the earthquakes of October 2016; (b) The church in November 2017.

5. Conclusion

During a seismic emergency, securing the damaged built heritage represents a complex problem, where the necessity to promptly react in order to limit further damage is hindered by the presence of different operators that belong to many Agencies. Indeed, this means that it is necessary to respect not only the specific emergency exigences, but also the rules proper of each Agency and of each one of the affected Regions.

As the case study has shown, the time of the intervention has a primarily importance. In order to enhance this aspect, it is necessary to provide a good level of interoperability among the involved experts and technicians, also through previous experiences and collaborations performed directly on the field, i.e. with preventive on site exercises and a continuous training for the specialized teams. In addition to this, it is also indispensable to provide an adequate knowledge of the buildings where it could be necessary to intervene during an emergency, aiming to perform rapidly the securing interventions and to design them adequately respect to the vulnerability of the buildings.

Thus, the preparedness to risk of the involved operators is an essential part for the protection of the damaged built heritage. Reaching a good level of this preparedness already before the occurrence of a seismic emergency can be performed through joined exercises and training activities, and through the preparation of both materials and means, as well as the knowledge on the existing vulnerability and characteristics of the historic buildings. This preventive preparedness would permit to avoid an irreversible progression of damage to the heritage, also reducing further collapses provoked by the subsequent seismic aftershocks.

The case study of the securing intervention of the church of 'Madonna del Sole' in Capodacqua has demonstrated that it is possible to reach this kind of preparedness.

Acknowledgements

The topic of the article was part of the subject of an interdisciplinary PhD in 'Preservation of the Architectural Heritage', carried out jointly between the departments DAStU and DABC of the Politecnico di Milano between 2019 and 2021. The authors wish to thank in particular the NFB of Ascoli Piceno, the UCCR office and the Regional Secretariat of Marche, the Superintendence of Ancona and the State Archives of Ascoli Piceno for the support provided both in the research and the consultation of the projectual and historical documents.

References

Accardo, G., Cacace, C. and Rinaldi, R., 2005. Il Sistema Informativo Territoriale della carta del Rischio. Arkos. Scienza e Restauro dell'Architettura – nuova serie, VI (3), pp. 43-52.

Acierno, M., Cacace, C. and Giovagnoli, A., 2014. La Carta del Rischio: un approccio possibile alla manutenzione programmata. Il caso di Ancona. Materiali e strutture: problemi di conservazione – nuova serie, III (5-6), pp. 81-106.

Bellizzi, M., 2004, Le opere provvisionali nell'emergenza sismica. Agenzia di Protezione Civile, Roma.

Brusa, E., 2021. The Italian emergency management for the built heritage after the 2012 earthquake: Emilia-Romagna and Lombardy, in "*Historic Cities in the Face of Disasters".* In: Arefian F., Ryser J, MacKee J, Hopkins, A. (Eds). Springer, Cham (Switzerland), pp.435-451.

Brusa, E., Chesi, C. and Della Torre, S., 2022. Architectural Heritage and seismic vulnerability: mapping the available knowledge for reducing damage during an emergency, in "HERITAGE2022 – Proceedings of the International Conference on Vernacular Heritage: Culture, People and Sustainability". Universitat Politècnica de València, Spain.

Cacace, C., 2019. La carta del rischio per il patrimonio culturale, in "Il futuro dei centri storici - Digitalizzazione e strategia conservativa". In: Fiorani, D. (Ed.). Quasar, Roma, pp. 65-74.

Caciolai, M., Bellizzi, M., Bolognese, C., Cavriani, M., D'Odorico, A., Maiolo, A., Mannino, E. Munaro, L., Ponticelli, L, Grimaz, A., Barazza, F. and Malisan, P., 2013. Timber provisional structures for post-earthquake emergency interventions. Ingegneria sismica, 30 (4), pp. 109-123.

Cavriani, M., 2014, Da lontano, dal basso e dall'alto: i lavori del Nucleo per il coordinamento delle opere provvisionali, in "Terra concussa: territori e architetture d'Abruzzo dopo il sisma del 2009 nel lavoro dei vigili del fuoco italiani". In: Cimbolli Spagnesi, P. (Ed.), vol.1, Roma, Aracne editrice, pp. 117-146.

Chiaraluce, L, Di Stefano, R, Tinti, E, Scognamiglio, L, Michele, M, Casarotti, E, Cattaneo, M, De Gori, P, Chiarabba, C, Monachesi, G, Lombardi, A, Valoroso, L, Latorre, D, Marzorati, S., 2017. The 2016 Central Italy seismic sequence: a first look at the mainshocks, aftershocks, and source models. Seismological Research Letters, 88 (3), pp. 757–771.

Della Torre, S. and Borgarino, M.P. (Eds.), 2014. Protezione dal rischio sismico, in "Proceedings of the international conference: Preventive and planned Conservation", vol.3, Nardini editore.

DPCM, 2011. Direttiva del Presidente del Consiglio dei Ministri per la valutazione e la riduzione del rischio sismico del Patrimonio culturale. DPCM 26/02/2011, G.U. n.54.

Fabiani, G., 1952, Cola dell'Amatrice secondo i documenti ascolani, Società tipolitografica editrice.

Grimaz, S., Barazza, F., Bellizzi, M., Bolognese, C., Cavrian, M., Caciolai, M., D'Odorico, A., Maiolo, A., Malisan, P., Mannino, E., Moretti, A., Munaro, L., Ponticelli, L. 2010. Manuale Opere Provvisionali. L'intervento tecnico urgente in emergenza sismica. Roma.

Grimaz, S., Cavriani, M., Mannino, E., Munaro, L., Bellizzi, M., Bolognese, C., Caciolai, M., D'Odorico, A., Maiolo, A., Ponticelli, L., Barazza, F., Malisan, P., Moretti, A. 2010. Vademecum STOP. Schede tecniche delle opere provvisionali per la messa in sicurezza post-sisma da parte dei Vigili del Fuoco. Roma.

Grimaz, S., Malisan, P. and Zorzini, F., 2018. Short-term countermeasures for securing cultural heritage buildings during a seismic emergency: improvements after the 1976 Friuli earthquake. Bollettino di Geofisica Teorica ed Applicata, vol.59, n.4, pp. 559-574.

ICCD, 2022, http://www.iccd.beniculturali.it/it/norme-regolamenti-circolari/4233/legge-364-1909-tutela-delle-cose-d-interesse-artistico-e-storico (accessed: 29.06.2022).

INGV, 2021. https://ingvterremoti.com/2016/08/26/sequenza-sismica-in-italia-centrale-la-sismicita-storica-dellarea/ (accessed: 24.11.2021)

INGV, 2022. https://ingvterremoti.com/2021/08/23/cinque-anni-dal-terremoto-del-24-agosto-2016/ (accessed: 29.06.2022).

Mastrodicasa, S., 2020. Puntelli e organi metallici di consolidamento, in "Dissesti statici delle strutture edilizie", IX, Hoepli, Milano, pp. 321 – 419.

MiBACT, 2015a. Procedure per la gestione delle attivita' di messa in sicurezza e salvaguardia del patrimonio culturale in caso di emergenze derivanti da calamita' naturali. Direttiva Ministero dei Beni e delle Attività Culturali e del Turismo 23/04/2015.

MiBACT, 2015b. Allegato 1 – strumenti schedografici. In: Procedure per la gestione delle attività di messa in sicurezza e salvaguardia del patrimonio culturale in caso di emergenze derivanti da calamità naturali. Direttiva Ministero dei Beni e delle Attività Culturali e del Turismo 23/04/2015.

MiBACT, 2016. Direttiva per le procedure di rimozione e recupero delle macerie di beni tutelati e di edilizia storica. Direttiva Ministero dei Beni e delle Attività Culturali e del Turismo 12/09/2016.

Negri, A., 2014. Conoscenza e catalogazione: la cooperazione tra sistemi informativi per la gestione dei dati prima e dopo l'emergenza. Materiali e strutture: problemi di conservazione – nuova serie, III (5 -6), pp. 55-80.

Parisi, M.A., Chesi, C. and Sferrazza Papa, G., 2018. Damage evolution in churches due to repeated earthquake shocks, in "Proceedings of the 16th ECEE European Conference on Earthquake Engineering", Thessaloniki, 18-21 June 2018.

Podestà, S. and Scandolo, L., 2017. L'assenza di opere di pronto intervento: l'evoluzione del danno nelle chiese a seguito degli eventi sismici del Centro Italia, in "ANIDIS 2017. L'ingegneria sismica in Italia – Proceedings of the XVII national conference". Pistoia, pp SS03-24–SS03-33.

Ranke, U., 2015. Natural Disaster Risk Management – Geosciences and Social Responsibility. Springer, pp.290-291.

Rossi, A., Tertulliani, A., Azzaro, R., et al., 2019. The 2016-2017 earthquake sequence in central Italy: macroseismic survey and damage scenario through the EMS-98 intensity assessment, Bulletin of Earthquake Engineering, 17, 2407 - 2431.

SogAt. VvF., 2016. Procedura per il funzionamento dei Gruppi Tecnici di Sostegno nella messa in sicurezza post-sismica di manufatti edilizi ai fini della salvaguardia della pubblica incolumità, della riduzione del rischio e del ripristino dei servizi essenziali. Circolare SogAt. VvF 18/09/2016, n.3/2016.

ViR, 2022. http://vincoliinrete.beniculturali.it/VincoliInRete/vir/vincolo/dettagliovincolo307350 (accessed: 29 June 2022).

Image References

Fig.1 – Image prepared by authors. The original values of the table were taken by the INGV website: http://terremoti.ingv.it/ (accessed: June 2022);

Fig.2 – Image prepared by authors;

Fig.3 – Image prepared by authors. The original photos were taken by the Diocesis of Ascoli Piceno. They are available on the website: https://www.iluoghidelsilenzio.it/oratorio-della-madonna-del-sole-arquata-del-tronto-ap/nggallery/page/1 (accessed: January 2021);

Fig.4, 5 – Diagram and image prepared by authors. The original photos (5a, 5b) were taken by the technicians of Mi.B.A.C.T. – U.C.C.R. Marche.