A BRIEF OVERVIEW OF THE WORLD, EUROPEAN, AND REGIONAL APPROACHES FOR POST-EARTHQUAKE DAMAGE ASSESSMENT OF BUILDINGS

Mihaela KOUTEVA-GUENTCHEVA
Faculty of Structural Engineering, Computer-Aided Engineering, University of Architecture, Civil Engineering and Geodesy, Sofia, Bulgaria
Tzvetan GEORGIEV
Department of Steel, Timber and Plastic Structures, University of Architecture, Civil Engineering and Geodesy, Sofia, Bulgaria
Lora RAYCHEVA
Faculty of Structural Engineering, Department of Steel, Timber and Plastic Structures, University of Architecture, Civil Engineering and Geodesy, Sofia, Bulgaria

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ABSTRACT

Post-earthquake damage assessment is both complex and of irreplaceable importance. Consequently, effective estimation of post-earthquake damages unavoidably requires professionally trained civil engineers, as it aims to identify, in general terms, whether a building or parts of it are safe to occupy either full time or for limited time periods. Once built, the different components of the built environment are in operation for 25, 50, 70, 100 and even more years. Thus, there is a disproportional ratio between constructions complying with current developments in engineering science and construction technologies and the existing ones— obviously to the benefit of the latter, addressing the following challenges: i) design and construction of new earthquake resistant buildings, facilities and technical infrastructure, and ii) damage assessment of the existing building stock after severe earthquakes. The four phases of the disaster management cycle require different relevant engineering approaches and skilled specialists. The expert knowledge on post-earthquake damage estimation within the leading countries in seismic engineering is here compared and overviewed. The Bulgarian experience of past earthquakes is also briefly commented. In conclusion, the need to develop a national three-step post-earthquake damage assessment methodology for buildings is justified.
Keywords: post-earthquake damage, earthquake, earthquake damage, damage assessment, earthquake engineering

1. INTRODUCTION

Modern societies need built environment. As the built structures operate for 25, 50, 70, 100 years and more, a skilled engineering community in designing and construction of new buildings and structures resistant to seismic events, but also in damage assessment of the existing building stock after the occurrence of strong earthquake is important. This is a quite complex and responsible task, and rapid professional and reliable post-earthquake damage assessment (Table 1) would be of essential importance for the timely response to the population in the affected region, and the proper organization of the immediate post-disaster management phase. This type of assessment aims at providing the society with rapid classification of damage and distinguishing between the buildings that are safe for occupancy and the unsafe ones, and the buildings for which additional detailed inspection and/or engineering analysis are needed. The types of damage reported allow the engineering community to make reasonable estimates of the response of different types of buildings and the vulnerability analysis of specific structural systems.

Some typical methods for assessment of damage and consequences from natural disasters (FEMA 2016) are currently adopted in practice worldwide, and briefly here listed: self-reporting, aerial, remote, and on-site inspections, geospatial analysis, and geographic information systems (GIS), predictive modelling (Table 1).

Table 1. Some typical methods for rapid post-earthquake damage assessment (FEMA 2016).

Method	Benefit	Drawback
Self-Reporting	• Leverages community and potential applicants to rapidly conduct initial damage assessments; • can be tailored to deliver more granular information	Information will need to be confirmed and intake systems must be in place at the time of the disaster to be effective
Fly-over surveys	Rapid assessment of damage	Damage must be easily observable from the air and the quality of information may not be adequate
Windshield Surveys	Efficient field-level assessment method	Damage must be easily observable

Door-To-Door and Site Assessments	Highly accurate	Time and labour intensive
Geospatial Analysis and Geographic Information Systems	Rapid assessment of damage and enhances analysis	GIS capabilities vary by administrative jurisdiction, state resources are often required for geospatial analysis. It can be difficult to discern specific damage details from GIS imagery.
Predictive modelling	Rapid identification of probable damage areas	Federal resources are often required to develop models and damage will need to be confirmed through ground-level assessments in most cases

Leading Expertise Worldwide

Contemporary methods for damage assessment of buildings after strong earthquake are primarily based on on-site inspection, combined (if necessary and/or possible) with some of the other abovementioned methods. Most methodologies for rapid post-earthquake damage assessment were elaborated in the 80's and 90's of the last century predominantly, as response to lessons learned from strong earthquakes that had occurred. Professionally developed methodologies are used in Japan, USA, New Zealand, Italy, Greece and many others.

In the USA (ATC, 2019), the three-stage procedure is defined for the assessment and separation of the buildings that are safe for occupancy from the unsafe ones and consists of: i) rapid assessment (in essence this is a "rough" inspection) of obviously hazardous and obviously habitable buildings; ii) detailed inspection, and iii) engineering inspection, which is carried out by a consultant engineer, hired by the owner of the building. Criteria for marking the inspected and categorized buildings with labels in three colors (green, yellow and red), considering the degree of safety for occupancy have been adopted. Forms for identification and brief description of the condition of the inspected buildings have also been elaborated. An important stage for the USA is the adoption of the *Disaster Recovery Reform Act*, *DRRA* during the 115th US Congress (2017-2018) with the participation of the Federal Emergency Management Agency (FEMA). The amendments consider crucial changes in the federal disaster programs, including joint responsibility at all levels of the national administration management for preparedness, managing the consequences, response and recovery after the occurrence of a disaster.

In Japan, the documents that regulate the methodologies for assessment of damage and rehabilitation of buildings after strong earthquakes date since 1991 (JBDPA 1991 revised in 2001). Modern development of in the field includes digitalization of the process of assessment, filling the respective forms and database management. A method for aerial view and mapping of buildings before and after an earthquake has been applied, including here the assessment of the degree of damage in the affected buildings has also been applied.

The unified Italian methodology (Baggio *et al*., 2007) is focused on the assessment of the usability of the building and the rapid vulnerability assessment, and the evaluation of visible damage. So, this methodology was tested in practice while implemented for the assessment of the damages after the earthquakes in the regions of Marche (1997), Basilicata and Calabria (1998), Molise Puglia (2002) and Abruzzo (2009). The L'Aquila (2009) earthquake emphasized the need for digitalization of the entire assessment process. The skills acquired from work experience were needed for an appropriate development and implementation of modules for digital planning of the inspection, field data collection and, publication and data processing. Everyone involved in the operation of buildings inspection process was trained to work with the digital platform in a developed learning program. The full and efficient conduction of the procedures in real emergency requires full integration of data collected from different platforms. This is supported by the national administration by a relevant implementation guide, introduced by a decree of the Prime Minister in 2008.

A field guide on Rapid Post Disaster and building usability assessment was issued in New Zealand in 2014 (MBIE 2014). This document is focused on the initial impact assessment and immediate public safety, not the provision of an engineering assessment service to building owners. Residential and non-residential buildings, specific structures and hazards, and instruction to complete the assessment forms are here addressed. The rapid post-quake assessment follows three major procedures: i) observation of the building exterior from street access; ii) walk around the building as far as possible and inspect each elevation, and iii) interior observations if safe to do so.

The Regional Balkan Expertise

The current Romanian methodology has the status of a regulation (MDPWH 200) and is published in the State Newspaper. In essence, it is a three-stage methodology for rapid assessment, consisting of: i) main rapid assessment, ii) technical rapid assessment, and iii) technical expertise. Each subsequent stage of the methodology, compared to the former stage, requires:

i) larger time for conducting the assessment, and ii) involvement of assessors with higher qualification.

Greece demonstrates an advanced methodology with elaborated and implemented modern tools - e.g., PEADAB (Gerbesioti 2004) that provides the valuable possibility for rapid acquisition of data by the specialized teams conducting the field inspections. In addition, it allows for appropriate data processing and specific damage and/or consequences analysis towards relevant informed decisions. Thus, priceless information is supplied to stakeholders to be used within the disaster prevention phase for: i) upgrade of the regulatory framework, ii) further elaboration of the systematic policies during the phase of developing the preparedness for response to the occurrence of possible strong earthquake, and iii) better organization of the preparedness phase.

The current Turkish methodology (Yilmaz *et al*., 2013) for rapid post-earthquake damage assessment does not differ significantly from the similar methodologies adopted in Romania or Greece. It is important to highlight that in Turkey it is established a specialized permanent administrative body managed directly by the Prime Minister called Disaster and Emergency Management Authority (AFAD), which implements a consistent policy in the field of seismic risk mitigation. A policy for compulsory insurance of the building stock for seismic events has also been adopted in the country and the scientific community elaborates methodologies for technical and financial earthquake damage assessment. Table 2 summarizes the post-earthquake damage assessment methodologies and some important national features.

All the aforementioned countries could be considered some of the most advanced countries in the field of post-earthquake operations. The characteristics of each country or region, and particularly the experience and construction traditions are considered in the relevant guiding manuals for damage assessment in buildings and structures. The most developed countries have relied on the pre-trained staff for the application of the methodology. Next level of preparedness provides a proper legal framework for post-earthquake operations and modern digital systems for collecting and processing of the information during the operations.

Table 2. Contemporary post-earthquake damage assessment methodologies in brief.

Country	Methodology	Governmental support
USA 1989	i. rapid assessment (essentially a 'rough' inspection) of obviously hazardous and apparently habitable buildings; R-Y-G indication ii. detailed assessment iii. engineering inspection carried out by a consultant engineer hired by the building owner	✓ September 1989 → Applied Technologies Council (ATC), Procedures for Assessing the Safety of Buildings after Earthquakes, known as ATC-20 and the Field Implementation Guide; 1987 → California Central Administration and Federal Emergency Management Agency (FEMA). ✓ Disaster Recovery Reform Act (DRRA) of the 115th US Congress (2017-2018) with the participation of the Federal Emergency Management Agency (FEMA).
Japan 1991		✓ The Japan Building Disaster Prevention Association (JBDPA), "Guideline for Post-earthquake Damage Evaluation and Rehabilitation", 1991 (revised in 2001) (JBDPA 2001).
Italy 1997		✓ developed and implemented modules for digital inspection planning, field data collection, publication, and processing of the collected data; developed training program for all persons involved in the operation for inspection of buildings to work with the digital platform; ✓ The integration of the data is supported by the state administration with a relevant implementation guide, introduced by a decree of the Prime Minister in 2008.
Romania 1940, 1999		✓ ME-003-99 Ministry of Development Public Works and Housing (MDPWH) ✓ Diverse functions are assigned to central and local government: (a) training work (specialists and experts) and (b) taking targeted measures for seismic reinforcement of buildings towards (1) continuously improve the methodology and (2) apply a systematic approach in the preparation phase for a strong earthquake.
Greece 2008		✓ developed and implemented computer system for data acquisition and processing → PEADAB
Turkey		✓ specialized body → permanent policy for seismic risk reduction, Disaster and Emergency Management Authority (AFAD) → managed by the Prime Minister of the Republic of Turkey; ✓ compulsory insurance of the building stock for seismic events.

New Zealand 2014	rapid assessment (essentially a 'rough' inspection) of obviously hazardous and apparently habitable buildings; R-Y-G indication	✓ National Recovery Office works with councils and government agencies to support a coordinated and efficient recovery after the devastating November 2016 earthquakes
Albania	National methodology – so far not developed	

Albania has been hit in the last 40 years by two strong earthquakes. No national methodology for rapid assessment of buildings is currently being implemented in the country. Criteria for post-earthquake building damage inventory and usability classification could be found in "Risk Assessment Albania - Executive Summary", Disaster Management and Emergency Preparedness Project, Annex A.2 (Koci 2022).

Nevertheless, during the operation after Durres (November 2019) Earthquake, instructions in English language were use, fig.1. In the same figure, it is shown a preliminary RDA Form used by the Construction Institute immediately after the earthquake of Nov. 26, 2019. After approval, this RDA Form was used for all post-earthquake damage assessments.

They were based on the damage classification for masonry and reinforced concrete structures. The latter are laid down in the European Seismological Commission, European Macroseismic Scale, by Grünthal, 1998 (Grünthal 1998). In fact, due to the specifics of the major resident building stock in Tirana, a unique building damage classification methodology and an official Rapid Damage Assessment (RDA) form was adopted by the Albanian government (Rangelov *et al*., 1987). Albanian earthquake engineers

The Bulgarian snapshot

In Bulgaria, first steps in the field were taken in the late 80's of the last century. Unfortunately, due to political turbulence and economic crises in the early 90's, the process has been soon subsided. The current Bulgarian approach for rapid post-earthquake damage assessment was set in 1987, fig.2. (Rangelov *et al*., 1987). Bulgarian draft of methodology was based on site inspections and application of a three-stage approach for damage assessment. It has been also accompanied by guidelines for assessing the degree of damage in structural and non-structural elements, filling forms, and marking the buildings inspected with colored stickers. The work done was highly professional, fully in line and competitive with respect to the world tendencies and achievements of the time. It has been a natural result of the active participation of Bulgarian specialists in the UNIDO project (UNIDO 1986), known in the country as “The Balkan Project”. The recent experience from the Pernik earthquake of 2012 (M = 5.6) (https://en.wikipedia.org/wiki/2012_Pernik_earthquake) was a real stress test for the preparedness of the Bulgarian society and engineering community, indicating the necessity of purposeful future work towards methodology for rapid post-earthquake damage assessment and relevant education of the engineering staff that is supposed to be involved.

Fig.1: a) Post-earthquake damage assessment, Durres, 2019. Four-storey masonry building in Tirana (common structural system for the city) and, b) General view of a completed form after a quick inspection of the building.

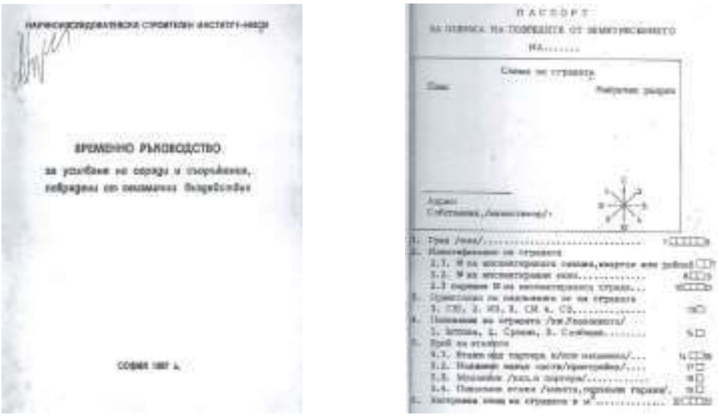

Fig. 2: Interim Handbook for strengthening of buildings and structures, damaged by earthquakes. Left- title page, right – start page of structural passport to be used for post-earthquake damage assessment (Rangelov *et al*., 1987).

1. CONCLUSIVE REMARKS

The need for elaboration of unified methodology for rapid post-earthquake damage assessment in Bulgaria is obvious. The majority of the existing buildings in Europe and Bulgaria, was built before the development and implementation of the modern codes for design of seismic resistant buildings and structures of 2010. Growing urbanization trend is an important factor influencing the seismic hazard exposure, seismic vulnerability, and seismic risk. The major reforms in the social-political system since the '90s in Bulgaria encompassed changes in the economic field, in the construction sector, in the expert engineering activity within the field of seismic risk mitigation. These changes together with the change of the professional generations during that period had quite negative influence on the Bulgarian preparedness for facing and adequate engineering response after a strong earthquake. Unfortunately, the Bulgarian engineering community and the responsible national institutions have lost the foundation laid in the late 80's as well as much precious time.

Given the high seismic hazard characterizing Bulgaria, the age of the building stock and the diverse training of the engineers, the gap-filling reaction after strong earthquakes would be crucial. Elaboration of national post-earthquake damage assessment methodology and further upgrade of the currently issued methodology for analysis, assessment and mapping of the seismic risk are crucial for reaching a reasonable level of preparedness. Working towards all methods for damage assessment will allow to perform realistic estimation of the current state of the built stock considering the earthquake loading history – action fully possible making use of modern tools for nonlinear dynamic structural analyses based on realistic modelling of scenario based seismic input (Kouteva-Guentcheva and Panza 2021). Professionally performed rapid post-earthquake damage assessment provides valuable data for validation of the results of these analyses. This necessary methodology elaboration and/or upgrade can be achieved by following the rich experience and relevant good practices of the leading countries in the field of seismic engineering and the management of seismic risk.

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