Determination of possible weak points of existing seismic risk management plans in tackling HR test site criticalities

Proposal of improvement to HR existing seismic risk management plans based on the results of the WP3

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Summary

Abstract

This document gives an overview on legal framework considering international and EU national legislation related to disaster risk assessment generally, with special focus on seismic risk assessment and management. Review of recommendations, platforms, directives and strategies for building the resilience to disasters in the Republic of Croatia at national, regional and local level is given. Existing strategies and plans for seismic risk management in the Republic of Croatia, at the regional (Split-Dalmatia County) and local level (City of Split, City of Kaštela), are compared to European guidelines in forecasting, prevention and management in crisis situations, as well as in the post-crisis period. The main steps in seismic risk assessment of the test site are discussed. Finally, considering the weaknesses and shortcomings of existing strategies and plans in Croatia, developed methodology and main findings of the project, the guidelines for improving existing seismic risk management plans are proposed.

1. Introduction

Throughout history, individuals and communities were exposed to the impact of earthquakes, which often resulted with major loss of life and destruction. The earthquakes cannot be considered only as natural disaster, because the main cause of the damage, injures and loss of human lives is insufficient resistance of the building stock and infrastructures. Therefore, it is easy to understand all the efforts taken to reduce seismic risks, i.e. taking of activities to prevent, adopt and reduce the impacts of seismic events.

For the last 20 years, an international acknowledgement that efforts to reduce seismic risks were systematically integrated into policies, plans and programmes for sustainable development and poverty reduction, and supported through bilateral, regional and international cooperation, including partnerships. Sustainable development, poverty reduction, good governance and seismic risk reduction are mutually supportive objectives, and in order to meet the challenges ahead, accelerated efforts must be made to build the necessary capacities at the community and national levels to manage and reduce risk.

The importance of promoting seismic risk reduction efforts on the international and regional levels as well as the national and local levels has been recognized in the past few years in a number of key multilateral frameworks and declarations. Mentioned policies, frameworks and declarations are the starting point for development of seismic risk management plan that define all phases of management comprising mitigation, preparedness, emergency response and recovery.

Seismic risk reduction through the effective approaches based on seismic risk assessment and development of management plans enables the achievement of global requirements given by different disaster risk reduction platforms like *The Sendai Framework for Disaster Risk Reduction 2015-2020* [1], *Hyogo Framework for Action 2005-2015* [2], *The Yokohama Strategy 1995-2005* [3], *Directive 2012/18/EU of the European Parliament and Council* [4] and *Decision no. 1313/2013/eu of the European Parliament and of the Council of 17 December 2013 on a Union Civil Protection Mechanism* [5]. In addition to the platforms that provide general guidelines for reducing all risks, the documents resulted from a number of international and European projects, conclusions from important workshops on seismic risk management, as well as numerous scientific papers dealing with seismic hazard, vulnerability and risk are important for the seismic risk management.

As a member of the United Nations, the Republic of Croatia was established a national platform for disaster risk reduction in 2009. The attention of the *Croatian platform for reduction of disaster risk* is focused on the implementation of the main priorities to reduce disaster risks. Another important organization is *National Protection and Rescue Directorate (DUZS) of Republic of Croatia,* which is responsible for organization of actions, tasks, drills and workshops in order to build the disaster resilience on the national level. The directorate is also responsible for preparing the Disaster Risk Assessment of the Republic of Croatia, a basic document for the development of disaster action plans for all entities in the protection and rescue system. The document *Disaster Risk Assessment for the Republic of Croatia* [7, 8] is a basis for drafting similar documents at the regional and local level [9, 10].

This document is organized as follows. General considerations related to seismic risk assessment and seismic risk management is given in Chapter 2. Chapter 3 gives an overview on legal framework considering international and EU national legislation related to disaster risk assessment generally with special focus on seismic risk assessment and management. Review of recommendations, platforms, directives and strategies for building the resilience to disasters in the Republic of Croatia at national, regional and local level is given in Chapter 4. Chapter 5 analyses differences, weaknesses and shortcomings of existing strategies and plans for seismic risk management in the Republic of Croatia, at the regional (Split-Dalmatia County) and local level (City of Split, City of Kaštela), in relation to European guidelines in forecasting, prevention, management in crisis situations and in the post-crisis period. Brief description of the main steps in seismic risk assessment of the test site, applied in this project, with focus on analysis of seismic hazard, vulnerability and seismic risk is elaborated in Chapter 6. Considering the weaknesses and shortcomings of existing strategies and plans in Croatia, developed methodology and main findings of the project, Chapter 7 gives guidelines for improving existing seismic risk management plans.

The main activities to reduce seismic risk of the existing urban area are directed to vulnerability and risk evaluation of existing structures and incentives for risk reduction by strengthening existing structures like strategic buildings, dwelling and historical buildings. In this project the methodology for vulnerability assessment on large scale, based on calculation of vulnerability indexes, is developed and demonstrated in the test site Kaštel Kambelovac, one of the seven settlements of the City of Kaštela (Fig. 1).

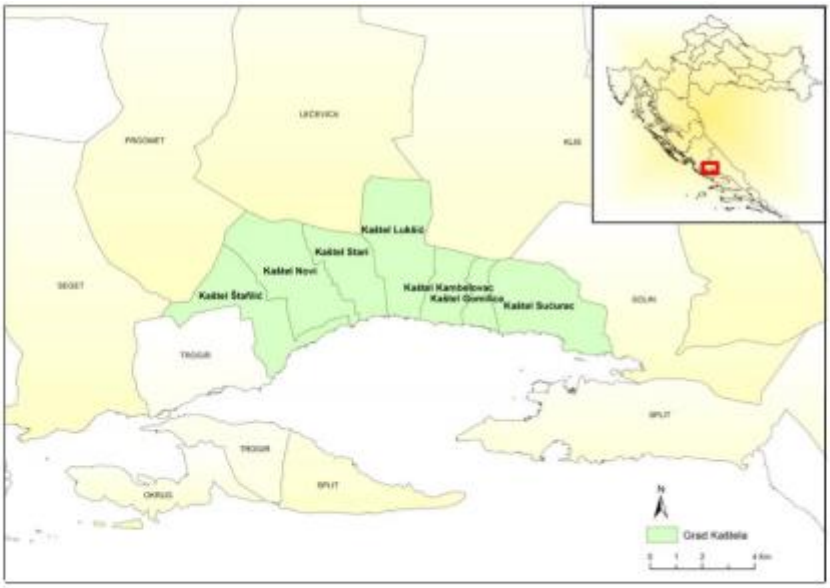


Fig. 1. Settlements and geographic position of the City of Kaštela [11]

The relevant area covers around 45000 square meters and includes more than 400 buildings. The settlement consists of a historical core with stone masonry buildings built between XV and XIX centuries (Fig. 2) and of the parts outside the historical core dating from the beginning of the XX century to nowadays (north, east and west parts in Fig. 3).

Fig. 2. A view of an old historical core, Kaštel Kambelovac

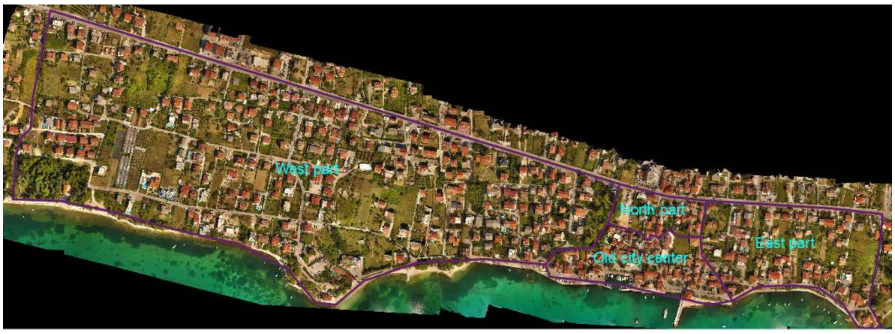


Fig. 3. Test site Kaštel Kambelovac with four characteristic parts

The buildings in the Kaštel Kambelovac were constructed in different periods according to different technical regulation. The oldest buildings were constructed before 1948; then, some blocks were erected from 1949 to 1964, from 1964 to 1982, and from 1982 to 2005. The most modern buildings have been built from 2005 onwards. Regarding to the specificity of the test site, the vulnerability assessment was proposed at two levels. The first one is classification of buildings according to their construction period considering the fact that application of different building codes in the past reflected on the structural earthquake resistance and vulnerability. The second level is categorization of the buildings according the vulnerability index. Seismic risk was expressed in terms of damage index and seismic risk index.

The main findings related to the vulnerability of the buildings and whole area are the basis for development of local strategies to reduce seismic risk which should be included into seismic risk management plan.

2. Seismic risk assesment and seismic risk management

2.1 Seismic hazard, vulnerability and risk

2.1.1 Earthquake definition

An earthquake is characterised by a series of vibrations on the earth's surface induce by generation of elastic (seismic) waves causes buildings to be pushed backwards and forwards and causes serious damage or even collapse if the buildings have not been constructed to anti-seismic criteria. Earthquakes can also generate secondary effects, such as landslides, tidal waves, land liquefaction and fires. The damaging potential of an earthquake depends on the depth between the hypocentre and epicentre, the distance between epicentre and position of the building, but also on local ground conditions.

The influence of the earthquake can be defined with magnitude and macroseismic intensity. Magnitude is a measure of energy released by the earthquake and it is commonly measured on Richter scale. Macroseismic intensity measures the effects caused by an earthquake, expressed in degrees on the Modified Mercalli intensity (MMI) scale, European macroseismic scale (EMS-98) or Medvedev Sponheur Karnik (MSK) scale.

Seismic risk represents a probabilistic measure of the damage expected in given interval. Risk depends on seismic hazard, on the vulnerability of the considered assets at risk and on the exposure.

2.1.2 Seismic hazard

Seismic hazard describes the level of ground shaking at the earth's surface which can be expected due to potential future earthquake activity. It is based on knowledge of past earthquakes, geology, and tectonics, and takes into account different factors that may affect the strength of the shaking at given location.

Seismic hazard assessment is the process of evaluating the design parameters of earthquake ground motion at any site. It can be performed in a deterministic or in a probabilistic framework. Deterministic description consider an earthquake scenario with a given magnitude and distance, often referred as event scenario. In the case of probability description, it expresses the probability of exceedance of levels of ground motion in a certain time interval and it is defined by probabilistic seismic hazard analysis. In both cases, the intensity of the seismic action is representative for a given probability of exceedance.

The seismic hazard assessment procedure involves the following steps: (1) the identification of potential earthquake zones by using the past earthquakes and seismic data; (2) the determination of earthquake parameters related to each zone; (3) the evaluation of seismic hazard for intensities and peak ground accelerations; and (4) the determination of seismic hazard at a site by using attenuation relations and site effects.

The most used design parameters are intensity and peak ground acceleration. Building dynamic response and damage are most often related to peak ground acceleration, especially since it is used as design parameter in calculation of lateral forces acting on a structure during an earthquake event. Therefore, modern seismic design codes are based on representation of the earthquake by peak ground acceleration.

The seismic hazard of the area usually represents with seismic hazard maps expressed in terms of the peak horizontal ground acceleration during an earthquake for certain return period. According to Eurocode 8 and corresponding Croatian norm [12, 13] the map for the return period of 475 years, with a probability of exceedance of 10% in 50 years, is used in designing earthquake resistant buildings. The map for the return period of 95 years, with a probability of exceedance of 10% in 10 years, is used in order to satisfy the fundamental requirements in damage limitation states.

2.1.3 Seismic vulnerability

Seismic vulnerability is a building's predisposition to be damaged and collapsed due to a seismic event of a given intensity.

One of the main causes of human lives during an earthquake is building collapse. To reduce the loss of human lives, buildings must be made safe. Laws governing construction in seismic zones today state that buildings must not be damaged by low-intensity earthquakes, must not be structurally damaged by medium-intensity earthquakes and must not collapse in the event of severe earthquakes despite suffering serious damage.

Seismic vulnerability of the buildings is calculated on the basis of various factors such as type od the structural system, age of the building, quality of materials, construction methods, location, vicinity to other buildings, non-structural elements, maintenance, etc.

There are different approaches for the evaluation of the structural vulnerability, depending on the level of detail of the typology of analysis and the sample of buildings. In case of the seismic vulnerability analysis of a large sample of buildings, for which the detailed analysis of each structure can be prohibitively expensive to perform, expeditious empirical methods is usually used. These methods are mainly based on qualitative evaluations. The approach is used for analysis on a territorial scale and it represents the first step in order to detect the most vulnerable buildings, which must be investigated with detailed analyses. Analytical/mechanical methods allow the study of the seismic vulnerability through analyses of the mechanical behaviour of the structure using the models with different levels of complexity. Recently, the hybrid methods, which presents the combination of two previous methods, are used to define seismic vulnerability of at urban scale. In that way, the empirical information coming from expeditious empirical survey can be combined with experimental and numerical tests to calibrate the vulnerability model for a specified site. The validity of the model is extended to small or medium urban areas characterized by repetitiveness of building typologies. The hybrid method can be used as a first estimation of the structural behaviour for the considered structures.

Information about the vulnerability of a territory given by vulnerability maps is really important in emergency phase because civil protection bodies have possibility to plan and manage operations with awareness of the territory and of the associated risks.

2.1.4 Seismic exposure

The exposure measures the quality and quantity of the "elements" exposed to the risk (in terms of human lives, economic resources, artistic or cultural ones ...). One of the main objectives for a general earthquake protection programme is safeguarding human life. Therefore, it is very important to assess the number of people involved, dead and/or injured.

There are various different causes for loss of human life during the earthquake: the collapse of buildings, bridges and other infrastructural systems, road accidents, etc. The phenomena such as landslides, land liquefaction, tidal waves and fires, triggered by the earthquake, can also causes the human losses. Various statistics obtained from major earthquakes around the world have shown that around 25% of deaths in an earthquake are due to none structural damage of buildings (falling partition walls, glass, cornices, roof tiles, etc.) and phenomena caused by the earthquake.

Estimation of number of people involved in the earthquake can be performed using calculations based on the number of collapsed or damaged buildings. Several considerations are needed to be able to make these estimates: the number of people living in the buildings, the time of the earthquake, the possibilities of escape and/or protection, how people were affected (dead or injured) and the possibility of dying even after aid has been given. It is very difficult to accurately estimate the consequences of an earthquake in terms of human lives at different times of the day and year. The number of people living in a house varies from region to region, from the city to the countryside and depends on the size of families. Additionally, the number of people present in a building depends on its use. Reference to the kind of buildings and relative inhabitants may provide a global estimate acceptable for violent earthquakes that affect large areas.

2.1.5 Seismic risk

The seismic risk is a function of three components: (1) the seismic hazard of the area, which expresses the probability that, in a given area and in a certain period of time, an earthquake of a given intensity occurs, (2) the vulnerability of the structure, which represents the trend of the structure to suffer damage due to a seismic event of a given intensity and (3) the exposure, which measures the quality and quantity of the elements exposed to the risk (in terms of human lives, economic resources,...). All of these elements contribute in the definition of the level of risk and they must be considered in the evaluation of the level of safety of an existing one.

Seismic risk can be expressed in terms of damage and in terms of consequences [14]. In a case of representing risk in terms of damage, the results are produced as conditional damage (with selected return period or intensity) or as unconditional damage (by selecting observation time window). Risk in terms of consequences is expressed through damage-impact relation which are establish to present consequences in terms of economic losses, unusable buildings and causalities. Damage distribution is a basis for calculation of the impact.

2.2 Seismic risk management

Seismic risk management aims to reduce or avoid the impact of earthquake and the potential losses, react during and after the earthquake, assure prompt and appropriate help to victims and achieve rapid and effective recovery [15].

Generally, seismic risk management consist of activities before a disaster, during a disaster and after a disaster. Predisaster activities aim to reduce human and property loos cause by earthquake hazard. During the disaster, emergency response activities are taken to meet the needs of the victims and reduce suffering to a minimum. After the disaster, activities that will ensure early recovery and rehabilitation of affected communities are taken (response and recovery activities).

The seismic risk management is based on a management cycle that is same as in the other disasters. Appropriate actions at all points in the cycle lead to greater preparedness, better warnings, reduced vulnerability and sometimes the prevention of new disasters. The complete seismic risk management cycle includes the making of public policies and plans that modify the causes of disasters or mitigate their effects on people, buildings, infrastructure and environment.

The disaster risk management cycle consists of four phases: mitigation, preparedness, response and recovery.

2.2.1 Mitigation

Mitigation activities in seismic risk management aim to prevent, eliminate or reduce the effects of the earthquakes. Mitigation measures include development and application of building codes, vulnerability analyses, seismic microzoning, land use management and public education. Mitigation depends on the introduction of appropriate measures in national and regional development planning and on the availability of information on hazards, vulnerability and risks. Mitigation measures are particularly focused on:

- Improving knowledge of the phenomenon, through the monitoring of the area and properly assessing the danger to which built-up areas, population and infrastructure systems are exposed;
- Implementing policies to reduce the vulnerability of older buildings, important buildings such as schools and monuments, strategic buildings such as hospitals, emergency management facilities;
- Upgrading the seismic classification and regulation
- Developing seismic microzoning studies as a basis for land-use planning that takes into account the seismic risk and to improve the operation and management standards of emergency after an earthquake;
- Acting on the population in order to increase the degree of awareness about seismic risk.

2.2.2 Preparedness

Preparedness activities aim to ensure a satisfactory level of readiness to respond to any emergency situation through programs that strengthen the technical and managerial capacity of governments, organizations, and communities. Preparedness activities have to ensure that emergency services and people at risk are aware of how to react during an event. These measures can be described as logistical readiness to deal with disasters and can be enhanced by having response mechanisms and procedures, rehearsals, developing long-term and short-term strategies, public education and building early warning systems. Preparedness measures are also focused to ensure strategic reserves of food, equipment, water, medicines and other essentials are maintained in cases of catastrophes. During the preparedness phase, governments, organizations, and individuals develop plans to save lives, minimize disaster damage, and enhance disaster response operations.

Preparedness measures include preparedness plans, emergency exercises/training, emergency communications systems, warning systems, evacuation plans and training, resource inventories, emergency personnel/contact lists, mutual aid agreements, and public information/education.

2.2.3 Response

The aim of emergency *response* is focused on the immediate needs of the population, such as the protection of life and property, emergency medical response, evacuation and transportation, decontamination, and the provision of food, water and shelter to victims and support the morale of the affected population. Such assistance may range from providing specific but limited aid, such as assisting refugees with transport, temporary shelter, and food, to establishing semi-permanent settlement in camps and other locations. It also may involve initial repairs to damaged infrastructure. The focus in the response phase is on meeting the basic needs of the people until more permanent and sustainable solutions can be found. Humanitarian organizations are often strongly present in this phase.

In a case of a seismic event, it is important to have the first information necessary for immediate aid, especially the size, extension and localisation of damage. In this phase assessment tools based on damage scenario simulations that allow planning and management of emergency response in real time are of crucial importance. These tools must be combined with activity to promptly assess the damage, to perform preliminary analysis and forecasts based on the first instrumental data obtained from the seismic monitoring network. In the event of earthquakes over the damage limit, prompt inspections are carried out with the aim of orienting and coordinating aid and resources during the emergency stage. This inspection consists of observing the level of damage and its distribution in the different locations. During the first hours after an earthquake, it is important to know as soon as possible the extent of the event and its impact in the area and on the population in order to activate, size and organise aid suitably. Activities focused on quick damage and agility assessment of public and private buildings and buildings of cultural interest play a fundamental role. In fact, these activities aim to safeguard public safety, guarantee the timely return of the population to their homes and carry out the first urgent measures to secure the buildings in order to reduce the disadvantage of the people affected and possible further damage.

2.2.4 Recovery

Recovery represents short and long term responses where the city authorities focus on clean-up and rebuilding. This can take months or even years. As the emergency is brought under control, the affected population is capable of undertaking a growing number of activities aimed at restoring their lives and the infrastructure that supports them. During the recovery period, there are many opportunities to enhance prevention, increase preparedness and reduce vulnerability.

Recovery activities continue until all systems return to normal or better. Recovery measures, both short and long term, include returning vital life-support systems to minimum operating standards, temporary housing, public information, health and safety education, reconstruction, counselling programs, and economic impact studies. Information resources and services include data collection related to rebuilding, and documentation of lessons learned [15].

2.2.5 Elements of seismic risk management in terms of duration

Seismic risk management activities in terms of duration can be classified into following categories.

Continuum activities for seismic risk reduction include:

- ongoing development activities in development programme;
- risk assessment to identify the risk;
- prevention to avoid the adverse impact of hazards;
- mitigation implying structural and non-structural measures undertaken to limit impact of the earthquake;
- preparedness activities and measures taken to ensure effective response;
- early warning system to give timely information to avoid or reduce risk.

Immediate disaster response encompass:

- evacuation from the affected area if necessary;
- protection of people and livelihoods during emergency;
- immediate assistance during or after earthquake;
- assessing damage and loss by ensuring information about impact of earthquake and loss.

Post-disaster to continuum response is focused on:

- continued assistance until certain level of recovery;
- recovery actions taken after the earthquake to restore infrastructures and services;

- reconstruction actions after the earthquake to ensures resettlements;
- economic and social recovery to normalized economy and societal living;
- risk assessment to identify new risks that communities may again face.

3. Overview on legal framework considering international and EU national legislation related to seismic risk assessment and management

3.1 Recommendations, platforms, directives and strategies for building the resilience to disasters on international level

Disaster risk reduction platforms define the main goals, priorities, global targets and guiding principles to reduce all recognized disaster risks. European and national risk reduction directives and strategies take into account the requirements and objectives set in several important frameworks for disaster risk reduction at the global level, and a brief overview of the most important ones is presented below.

3.1.1 Yokohama Strategy 1995-2005

The Yokohama Strategy for a safer world *Guidelines for Natural Disaster Prevention, Preparedness and Mitigation and its Plan of Action (Yokohama Strategy)* [3], adopted in 1994, provides landmark guidance on reducing disaster risk and the impacts of disasters.

Part I describes the principles on which a disaster reduction strategy should be based. Part II is a plan of action agreed upon by all member states of the United Nations. Part III gives some guidelines concerning the follow-up of action.

The review of progress made in implementing the Yokohama Strategy identified major challenges for in ensuring more systematic action to address disaster risks in the context of sustainable development and in building resilience through enhanced national and local capabilities to manage and reduce risk.

The review stressed the importance of disaster risk reduction being underpinned by a more pro-active approach to informing, motivating and involving people in all aspects of disaster risk reduction in their own local communities. It also highlighted the scarcity of resources allocated specifically from development budgets for the realization of risk reduction objectives, either at the national or the regional level or through international cooperation and financial mechanisms, while noting the significant potential to better exploit existing resources and established practices for more effective disaster risk reduction.

Specific gaps and challenges were identified in the following five main areas:

- Governance: organizational, legal and policy frameworks;
- Risk identification, assessment, monitoring and early warning;
- Knowledge management and education;
- Reducing underlying risk factors;

- Preparedness for effective response and recovery.

Drawing on the conclusions of the review of the Yokohama Strategy, and on the basis of deliberations at the World Conference on Disaster Reduction and especially the agreed expected outcome and strategic goals, the Conference has adopted the following five priorities for action:

- Ensure that disaster risk reduction is a national and a local priority with a strong institutional basis for implementation;
- Identify, assess and monitor disaster risks and enhance early warning;
- Use knowledge, innovation and education to build a culture of safety and resilience at all levels.
- Reduce the underlying risk factors;
- Strengthen disaster preparedness for effective response at all levels;

In their approach to disaster risk reduction, states, regional and international organizations and other actors concerned should take into consideration the key activities listed under each of these five priorities and should implement them, as appropriate, to their own circumstances and capacities.

3.1.2 Hyogo Framework for Action 2005-2015

A series of extraordinary catastrophes, triggered by natural hazards between 2003 and 2005, highlighted and reminded the world the degree to which disaster risk now underlies and threatens development. The Bam earthquake of December 2003 in the Islamic Republic of Iran, the heat wave that affected Western Europe in 2003, the devastation caused by Hurricanes Ivan and Jeanne in Grenada and other Caribbean countries in September 2004, the Indian Ocean earthquake and tsunami in December 2004, Hurricane Katrina in the United States of America in August 2005 and the Kashmir earthquake of October 2005, accounted for more than 350,000 deaths and USD 194 billion of economic damage. However, these catastrophes were only the most visible manifestations of the ongoing unfolding of disaster risk.

The response on these new challenges was the World Conference on Disaster Reduction held from 18th to 22nd January 2005 in Kobe, Hyogo, Japan. The result of the conference was adoption of the strategy *Building the Resilience of Nations and Communities to Disasters (Framework for Action)* [2] for period 2005-2015.

The Conference provided a unique opportunity to promote a strategic and systematic approach to reducing vulnerabilities and risks to hazards. It underscored the need for, and identified ways of, building the resilience of nations and communities to disasters.

In the Framework for Action the vulnerability was defined as: “The conditions determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards” (UN/ISDR, Geneva 2004). Furthermore, the hazard was defined as: “A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Hazards can include latent conditions that may represent future threats and can have different origins: natural (geological, hydro-meteorological and biological) or induced by human processes (environmental degradation and technological hazards)" (UN/ISDR, Geneva 2004).

The scope of this Framework for Action encompasses disasters caused by hazards of natural origin and related environmental and technological hazards and risks. It thus reflects a holistic and multi hazard approach to disaster risk management and the relationship, between them which can have a significant impact on social, economic, cultural and environmental systems, as stressed in the Yokohama Strategy.

3.1.3 Sendai Framework for Disaster Risk Reduction 2015-2030

The Third UN World Conference on Disaster Risk Reduction, held in Sendai City, Miyagi Prefecture, Japan 18th March 2015, resulted with the Sendai Framework for Disaster Risk Reduction 2015-2030 [1], which was adopted by UN Member States on 18th March 2015. The Sendai Framework is the first major agreement of the post-2015 development agenda, with seven targets and four priorities for action.

The present framework can be applied to the risk of small-scale and large-scale, frequent and infrequent, sudden and slow-onset disasters, caused by natural or manmade hazards as well as related environmental, technological and biological hazards and risks. It aims to guide the multi-hazard management of disaster risk in development at all levels as well as within and across all sectors.

Main goal is to prevent new and reduce existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience.

The global targets of the framework are as follows:

- Substantially reduce global disaster mortality by 2030, aiming to lower average per 100,000 global mortality in 2020-2030 compared to 2005-2015;
- Substantially reduce the number of affected people globally by 2030, aiming to lower the average global figure per 100,000 in 2020-2030 compared to 2005-2015;
- Reduce direct disaster economic loss in relation to global gross domestic product (GDP) by 2030;
- Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030;
- Substantially increase the number of countries with national and local disaster risk reduction strategies by 2020;

- Substantially enhance international cooperation to developing countries through adequate and sustainable support to complement their national actions for implementation of this framework by 2030;
- Substantially increase the availability of and access to multi-hazard early warning systems and disaster risk information and assessments to the people by 2030;
- Through adequate and sustainable support to complement their national actions for implementation of this framework by 2030.

There is a need for focused action within and across sectors at local, national, regional and global levels in the following four priority areas:

- Priority 1: Understanding disaster risk;
- Priority 2: Strengthening disaster risk governance to manage disaster risk;
- Priority 3: Investing in disaster risk reduction for Priority Understanding disaster risk resilience
- Priority 4: Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction.

Guiding principles are:

- Primary responsibility of states to prevent and reduce disaster risk, including through cooperation;
- Shared responsibility between central government and national authorities, sectors and stakeholders as appropriate to national circumstances;
- Protection of persons and their assets while promoting and protecting all human rights including the right to development;
- Engagement from all of society;
- Full engagement of all state institutions of an executive and legislative nature at national and local levels;
- Empowerment of local authorities and communities through resources, incentives and decision-making responsibilities as appropriate;
- Decision-making to be inclusive and risk-informed while using a multi-hazard approach;
- Coherence of disaster risk reduction and sustainable development policies, plans, practices and mechanisms, across different sectors;
- Accounting of local and specific characteristics of disaster risks when determining measures to reduce risk;

- Addressing underlying risk factors cost-effectively through investment versus relying primarily on post-disaster response and recovery;
- "Build Back Better" for preventing the creation of, and reducing existing, disaster risk;
- The quality of global partnership and international cooperation to be effective, meaningful and strong;
- Support from developed countries and partners to developing countries to be tailored according to needs and priorities as identified by them.

3.2 Recommendations, platforms, directives and strategies for building the resilience to disasters on EU level

3.2.1 Directive 2012/18/EU of the European Parliament and Council

In July 2012, the European Parliament and the Council agreed on Directive 2012/18/EU on the control of major-accident hazards involving dangerous substances [4], amending and subsequently repealing Council Directive 96/82/EC.

Council Directive 96/82/EC of 9 December 1996 on the control of major-accident hazards involving dangerous substances laid down rules for the prevention of major accidents which might result from certain industrial activities and the limitation of their consequences for human health and the environment. Since major accidents often have serious consequences, the impact can extend beyond national borders. This underlined the need to ensure that appropriate precautionary action is taken to ensure a high level of protection throughout the Union for citizens, communities and the environment. There is therefore a need to ensure that the existing high level of protection remains at least the same or increases. A review of that Directive has confirmed that some changes are required in order to further strengthen the level of protection, in particular with regard to the prevention of major accidents. At the same time the system established by Directive 96/82/EC should be adapted to changes to the Union system of classification of substances and mixtures to which that Directive refers. In addition, a number of other provisions should be clarified and updated. All these issues were addressed in the new directive 2012/18/EU. Although the directive places great emphasis on dangerous substances, its provisions also apply to other risks.

From the point of view of risk management and the development of risk management plans, articles 12, 13 and 14 of Directive 2012/18/EU are of particular importance, which consider emergency planning, land use planning and informing the public about risk events.

An obligation to prepare *emergency plans* (Article 12) is defined with the following objectives:

- containing and controlling incidents in order to minimise the effects, and to limit damage to human health, the environment and property;
- implementing the necessary measures to protect human health and the environment;

- communicating the necessary information to the public and to the services or authorities;
- providing for the restoration and clean-up of the environment after a major accident.

The content of the emergency plan is defined in Annex IV.

The Directive prescribes that the objectives of preventing major accidents and limiting the consequences of such accidents for human health and the environment are taken into account in their land-use planning or other relevant policies (Article 13). Those objectives should be realized through controls on the siting of new and modification of existing establishments, as well as new developments including transport routes, locations of public use and residential areas in the vicinity of establishments, where the siting or developments may be the source of or increase the risk or consequences of a major accident.

All information about accident (Article 14) should be permanently available to the public, including electronically. The information shall be kept updated, where necessary, including in the event of modifications. Items of information to the public is defined in Annex V.

3.2.2 Decision no. 1313/2013/EU of the European Parliament and of the Council on a Union Civil Protection Mechanism

The Union Civil Protection Mechanism is defined by the Decision no. 1313/2013/EU of the European Parliament and of the Council of 17 December 2013 [5]. The main aim of the Decision is to strengthen the cooperation between the Union and the Member States and to facilitate coordination in the field of civil protection in order to improve the effectiveness of systems for preventing, preparing for and responding to natural and man-made disasters. The protection covers primarily people, but also the environment and property, including cultural heritage, against all kinds of natural and man-made disasters. The Decision lays down the general rules for the Union Mechanism and the rules for the provision of financial assistance under the Union Mechanism.

The specific objectives of the Decision are as follows:

- to achieve a high level of protection against disasters by preventing or reducing their potential effects, by fostering a culture of prevention and by improving cooperation between the civil protection and other relevant services;
- to enhance preparedness at Member State and Union level to respond to disasters;
- to facilitate rapid and efficient response in the event of disasters or imminent disasters;
- to increase public awareness and preparedness for disasters.

Prevention actions include action to improve the knowledge base on disaster risks and facilitate the sharing of knowledge, best practices and information, to support and promote risk assessment and mapping activity, to establish and regularly update a cross-sectoral overview and map of natural and man-made disaster risks, to encourage an exchange of good practices on preparing national civil protection systems, to promote and support the development and implementation of risk management activity, to compile and disseminate the information and to promote prevention measures.

An Article 6 of the Decision is of the special importance because the Member States shall:

- develop risk assessments at national or appropriate sub-national level and make available to the Commission summary of the relevant elements there of by 22 December 2015 and every three years thereafter;
- develop and refine their disaster risk management planning at national or appropriate sub-national level;
- make available to the Commission the assessment of their risk management capability at national or appropriate sub-national level every three years following the finalisation of the relevant guidelines and whenever there are important changes;
- participate, on a voluntary basis, in peer reviews on the assessment of risk management capability.

Preparedness measures mainly contribute to development and better integration of transnational detection and early warning and alert systems, to establish and manage the capability to mobilise and dispatch expert teams, to establish and maintain the capability to provide logistical support for those expert teams, develop and maintain a network of trained experts, support the creation of voluntary peer review assessment programmes.

The Decision also defines response in the event of a disaster and the financial envelope for the implementation of the Union Mechanism.

3.2.3 Earthquake risk reduction in the European Union

Earthquake is a serious threat in European Union, but it was also recognized that the main cause of the damage, injures and/or loss of human lives is insufficient resistance of the building stock and infrastructures. Significant effort to reduce seismic risk is done with the Eurocodes, through the promotion of Civil Protection and support of the research projects. However, the old buildings and infrastructures built long before the approval of the current seismic regulation contribute to significant damage and demolition of such buildings and numerous causalities.

The first organized discussion on this problem at the European level in 2000, initiated intensive work of the European Association for Earthquake Engineering with EU Commission and other international organizations to define and establish set of policies to reduce earthquake risk at local, national and EU level. In 2005 the European Association for Earthquake Engineering and the Portuguese Society for Earthquake Engineering, under the support of European Commission’s Joint Research Centre and UK society for Earthquakes and Civil Engineering Dynamics, organized workshop to define strategies and actions to reduce seismic risk in Europe. The result of the workshop is document *Earthquake risk reduction in the European Union* [16].

The earthquake occurrence and distribution of earthquake hazard in Europe has shown the zones of the high seismic risk.

The main consequences of the earthquake at the earth's surface (fault rupture, landslides, subsidence and liquefaction, tsunamis and ground motion / ground shaking, fires) and actions to reduce these effects are defined. Possible actions are given as follows:

- Fault rupture: Actions include not building across potential active faults except in extreme situations.
- Landslides, subsidence and liquefaction: To avoid building in these zones or built taking adequate precautions like stabilization of the soil.
- Tsunamis: Actions include (1) creation and maintenance of monitoring systems, (2) information and preparation of the population, (3) avoid the construction of the facilities with large concentration of the people (hospitals, schools, homes of elderly people with low mobility) and facilities with potential to cause environmental disaster, using territorial and urban planning instruments; (4) design to resist predictable levels of tsunami actions;
- Ground motion / ground shaking: Ground motions cause more than 80% of the human and economic losses. Therefore, it is crucial to build constructions and infrastructures that resist earthquakes. The scientific knowledge of the seismology is used to estimate the probability of the exceedance of earthquake in given zones, which is the basis for seismic design according to the structural codes. Applying earthquake engineering knowledge has the capability to design and built earthquake resistant structures and equipment. The main actions include: (1) evaluation of the seismic resistance of existing building and strengthening those with insufficient seismic resistance, particularly the buildings built before 1980, (2) ensure the quality of new constructions as well as strengthening existing ones, (3) evaluate the seismic resistance of lifelines and transportation networks and strengthen if necessary, (4) evaluate the seismic resistance of industrial facilities and strengthen if necessary, (5) strengthen monuments and buildings of high cultural value.
- Fires: They can take place during and after the earthquake and cause significant damage and loss of live. Actions include education of the population to minimize the risks of the fires at private houses and offices and design of gas network.

The role of Civil Protection actions in post-event actions is also discussed, especially: (1) in search and rescue operations which can reduce the number of victims and reduce damage, (2) in recovery of the population and economy of the affected zones, providing support to the survivors, identification of safe and unsafe buildings and facilities and other activities important to bring the area to normality.

The document also discuss importance of political background in EU and European dimension of the problem of natural catastrophes that is implicitly introduced in EU decisions and policies. The examples are: (1) support to research in the field of seismology and earthquake engineering, (2) the development of structural codes, especially Eurocode 8, (3) establishment of a centre for coordination of emergency aid which is important to optimisation of Civil Protection resources.

The main action for the reduction of the seismic risk, proposed for potential application of EU funds are:

- Territorial and urban planning;
- Informing and preparation of the population;
- Evaluation of the seismic resistance of existing building and strengthening those with insufficient seismic resistance (strategic and current buildings);
- Ensuring the quality of construction;
- Evaluation of the seismic resistance of lifelines and transportation networks and strengthen if necessary;
- Evaluation of the seismic resistance of industrial facilities and strengthen if necessary;
- Strengthening monuments and buildings of high cultural value;
- Civil Protection actions.

The role of codes, especially Eurocode 8, in the reduction of earthquake risk is analysed.

Possible actions to support Civil Protection can be summarized as follows:

- Risk reduction: (1) more careful land-use planning in view of seismic risk aspects and sustainability, development and improvement of the products for design and construction practice and education and training through the continuing educational programs, (2) promotion of activities for vulnerability and risk evaluation of existing structures, (3) incentives for risk reduction by strengthening existing structures like strategic buildings, dwelling buildings, lifeline structures should be promoted and local government should be supported;
- Mitigation of earthquake effects after an event: (1) improving preparedness in emergency operations through training programmes that consist of three components: courses, simulation exercises and exchange of experts systems, (2) improving monitoring and early warning systems, (3) improving survey methods for after-event operability assessment of buildings and lifelines.
- Inter-government collaboration and use of the EU resources for emergency situations to help the affected region is important in the case of large earthquake.

3.2.4 European Strategic Research Agenda on Earthquake Risk: Vision and Roadmap for implementation

The seismic risk reduction strategy issued in 2007 [16], has stimulated the implementation of several research European projects in FP7 program (i.e. SERIES, NERA, SYNER-G, SHARE, REAKT…) that dealt with seismic risk and included various scientific areas, from earthquake engineering and seismology to social and economic sciences. Document European *Strategic Research Agenda on Earthquake Risk: Vision and Roadmap for implementation* [17], published in 2013, arose as a result of previous strategies and research results, and gave a new impetus to creation a resilient European society. After a series of devastating earthquakes in the world, it was recognized that significant efforts should be undertaken to better definition of the hazard and the development of previously defined earthquake mitigation approaches.

This document analyses the current situation in the field of seismic risk research, pays special attention to the previous document issued in 2007 [16], and highlights the new objectives that need to be achieved in order to reduce the consequences of harmful seismic events. The recommendations in this document are not binding, but it suggests in which areas of research Europe needs to invest in order to increase the security of its citizens and property from adverse events.

One of the emphasis of the document is on the reduction of earthquake risk through the assessment and retrofit of existing structures. The document recognized the problem of existing buildings in European urban areas, dating back to the mid-XX century and earlier, which cannot be treated as individual buildings as they constitute entire blocks of constructions where the different buildings are interdependent. These buildings are often of great historical value and undergo preservation works. Therefore, it is important to set up appropriate assessment and design methods and rules.

The role of Civil Protection is also emphasized, as well as its contributions to prevention and preparedness, for instance by means of information on how the population can and must act before and during earthquakes. Therefore, in tackling the earthquake problem, Civil Protection actions must be regarded as an indispensable and important complement of the main preventive policies, and research at a European level should consider means to make pre- and post-event Civil Protection actions more effective.

4 Overview of recommendations, platforms, directives and strategies for building the resilience to disasters in the Republic of Croatia at national, regional and local level

4.1 Analysis of legal framework for disaster reduction

National laws, regulations and guidelines prescribe seismic risk management in the Republic of Croatia, together with all other risks through the platform for disaster risk reduction.

As a member of the United Nations, the Republic of Croatia was obliged to establish a national platform for disaster risk reduction in accordance with the conclusions of the UN *World Conference on Disaster Risk Reduction*, held in January 2005 in Kobe, Japan, and *Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters*, which defines the directions of action in the development of protection and rescue in the world for the period until 2015. Therefore, four years after the Hyogo framework, the *Croatian platform for reduction of disaster risk* was established in Zagreb in 2009.

The attention of the *Croatian platform for reduction of disaster risk* is focused on the implementation of the following five priorities:

- Ensure that disaster risk reduction policy is a national and local community priority, with a strong institutional basis for its implementation;
- Identify, assess and monitor disaster risks and develop an early warning system;
- Use knowledge, innovation and education to develop and build a security and resilience at all levels;
- Reduce existing disaster risks;
- Strengthen preparedness for effective disaster response.

It is worth mentioned that the national platform is focused much more on pre-disaster activities and significantly less on post-disaster response activities, although the platform should also discuss the community's capacity to strengthen response capacity, which includes developing forces for action, coordinating operational actions, strength of all participants, provision of logistical support, provision of capacity to accommodate vulnerable populations, coordination of actions at all levels, from families, through local and regional self-government units to the state level.

National Protection and Rescue Directorate (DUZS) of Republic of Croatia is responsible for organization of actions, tasks, drills and workshops in order to build the disaster resilience on the national level. The directorate is also responsible for preparing the Disaster Risk Assessment of the Republic of Croatia. The assessment is a basic document for the development of disaster action plans for all entities in the protection and rescue system, from central state administration bodies to operational forces (fire brigade, CZ, legal entities dealing with protection and rescue, citizens' associations), and also serves regional units and local governments in making their vulnerability assessments.

As a member of the European Union, Croatia has adopted numerous obligations related to the disaster risk management. In accordance to Directive 2012/18/EU [4] and the Decision 1313/2013/EU (Article 6) of the European Parliament and of the Council of 17 December 2013 on a Union Civil Protection Mechanism [5], member countries were required to submit disaster risk assessment summaries to the European Commission (EC) by 22 December 2015. In 2014, Croatian Government issued the Decision to start the procedure for fulfilment of appropriate objectives. It resulted with the document *Disaster Risk Assessment for the Republic of Croatia* [7] in November 2015, made in accordance with the *Ordinance on the methodology for preparing vulnerability assessments and protection and rescue plans* (NN 30/14 and 67/14) [18]. According to the *Law on Civil Protection System* (NN 82/15 and 118/18) [19], the Government of the Republic of Croatia adopts the updated document *Disaster Risk Assessment for the Republic of Croatia* in 2018 [8], fulfilling the *Ordinance on Guidelines for the Development of Disaster Risk and Major Accident Risk Assessments for the Republic of Croatia and Local and Regional Self-Government Units* (NN 65/2016) [20], the Risk Assessment and Mapping Guidelines for Disaster Management SEC (2010) 1626 [21], and HRN ISO 31000 Risk Management [22].

The document *Disaster Risk Assessment for the Republic of Croatia* [8] is a basis for drafting similar documents at the regional and local level. In all mentioned documents, seismic risk was recognized as unacceptable for the community.

4.2 Disaster Risk Assessment for the Republic of Croatia

4.2.1 Disaster Risk Assessment for the Republic of Croatia (2015)

The first version of the document *Disaster risk assessment for the Republic of Croatia* [7] date from 2015. This assessment was based on Guidelines for the Preparation of National Disaster Risk Assessment for the Republic of Croatia issued by the National Protection and Rescue Directorate (2014) in accordance with the Risk Assessment and Mapping Guidelines for Disaster Management SEC (2010) 1626 [21], and HRN ISO 31000 Risk Management [22]. One of the main objectives of the guidelines was to ensure comparability of individual risk assessments, both on the national level and on the EU level. In this document only part related to earthquake risk is analysed.

Seismic hazard

Considering that the Republic of Croatia belongs to the Mediterranean-Trans-Asian zone of high seismic activity, according to the European Seismic Hazard Map (Fig. 4a) [23] it is one of the most seismically endangered countries in Europe. The coastal area is most exposed to earthquakes, especially southern Dalmatia and north-western Croatia [24]. Fig. 4b shows the epicentres of all earthquakes in Croatia from 373 BC. Kr. until 2011, and Fig. 4c with appropriate years among them stands out earthquakes with the greatest magnitudes [25]. The worst-case scenario for the Croatia was selected as the ground shaking in the City of Zagreb caused by an earthquake with return period defined in regulations for the design of seismic resistance. The scenario includes two levels of earthquake corresponding to the return period accepted in the current regulations for earthquake resistance design (Eurocode 8 [12, 13]), i.e. 95 years for the most probable adverse event (weaker earthquake) and 475 years for the event with the worst possible consequences (stronger earthquake), Fig. 5. The influence of local soil conditions was not taken into account.

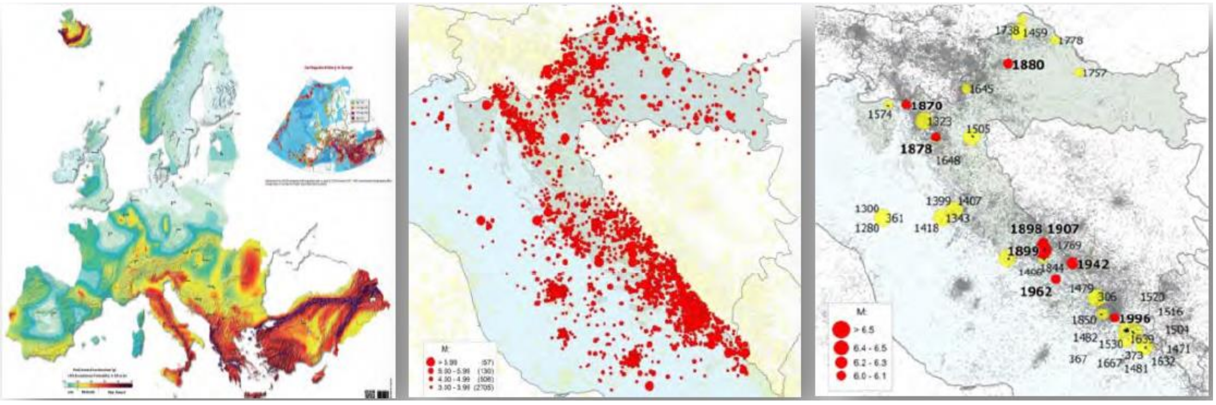


Fig. 4. (a) Seismic hazard map in Europe [23]; (b) Earthquake epicentres in Croatia from 373 BC. Kr. until 2011 [24]; (c) Epicentres of the largest earthquakes in Croatia [25].

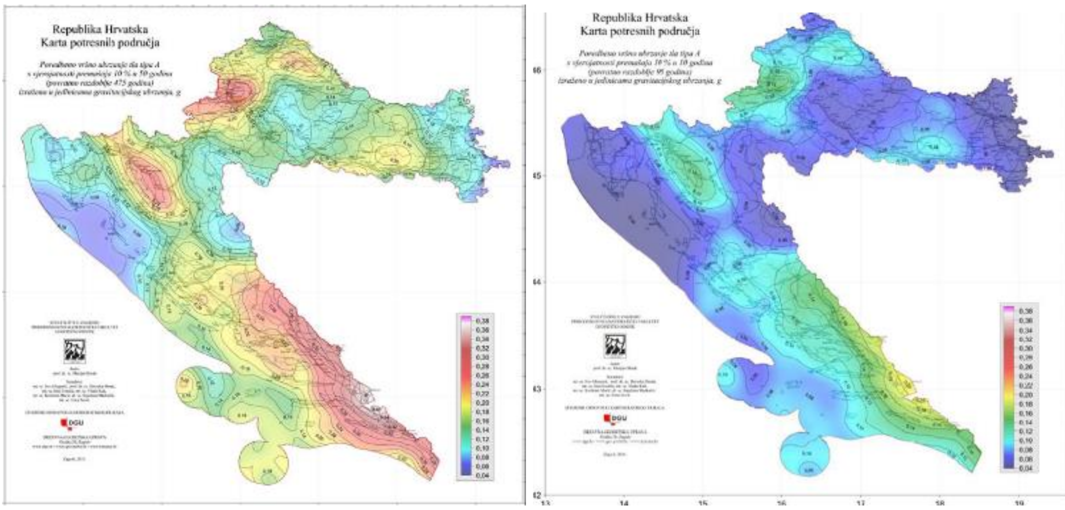


Fig. 5. Seismic hazard maps for Republic of Croatia (PGA) for return periods: (a) 475 years; (b) 95 years [13]

Exposure of existing buildings

The existing building stock is categorized according to the characteristic types of buildings and load-bearing structures, i.e. the method of construction, with appropriate construction periods. The categorization was made only for the City of Zagreb.

Vulnerability and damage assessment of buildings

Assessing possible earthquake losses in seismically active areas is extremely important for implementing a risk mitigation strategy and planning emergency interventions in the event of a catastrophic event, and is therefore of particular interest to government authorities, but also to engineers in practice and the community. The assessment and expected behaviour of buildings is based on determining the prevalence of damage, which according to the extent of adverse impact on the load-bearing capacity of the structural system of the building is classified into five levels using European Macroseismic scale EMS-98 [26]. Vulnerability and damage assessments supplemented with expert assessments based on knowledge and experience with regard to specific local conditions (illegally constructed buildings, faults, landslides, quality of construction, specific typology of construction, etc.). Estimates are very rough given the lack of reliable parameters, contain subjective elements but also a number of specific limitations such as:

- There are no systematized databases on the typology of construction, and there are a number of specific types of buildings such as prefabricated buildings such as Jugomont JU-60, buildings built with tunnel formwork;
- A large number of illegally constructed buildings (without valid documentation) which include unfavourable interventions (e.g. demolition of load-bearing walls for shop windows) in the load-bearing structure, i.e. change of essential requirements for the building;
- Uncertainty in assessing the vulnerability of certain buildings due to differences in knowledge about old buildings in relation to buildings designed in accordance with modern regulations;
- There are no data on the construction of buildings, materials used, possible construction errors, subsequent repairs;
- Buildings are usually designed for a lifespan of 50 years which is exceeded (material degradation) in most of the existing housing stock.

Presentation of consequences

Assessment of consequences for the building stock is made according to available databases, previous experiences, recommended literature and specially made forms.

The assessment of the consequences on human life and health is mostly related to the degree of damage to buildings, because without detailed research it is not possible to accurately estimate the number of dead and deeply, medium and shallowly buried. The consequences were estimated according to the number of endangered buildings. Therefore, the uncertainty of the assessment is related to the uncertainties in assessment of damage to buildings, but given the set criteria it is concluded that it will exceed many times the criterion of catastrophic consequences.

The assessment of the consequences for the economy was linked to direct and indirect losses. The direct consequences are also directly related to damage to buildings, i.e. uncertainties in the assessment are related to uncertainties in the assessment of damaged buildings.

The assessment of the consequences for social stability and policy was related to the damage to the buildings in which key institutions are located and the damage to critical infrastructure. The fact that most of all buildings were built before 1964, i.e. before the first regulations that significantly take into account seismic action (significantly endangered) and given the high concentration of many elements of critical infrastructure, a catastrophic impact was assessed.

The individual elements of the critical infrastructure have not been analysed because they require extensive research, so the assessment was made on the basis of context and in comparison with some existing data. However, the document emphasis that, between the possible consequences due to the impact on the infrastructure and strategic facilities of the urban area affected by the earthquake, the special mention should be made of:

- Direct damage to roads due to earthquakes or their impassability due to secondary consequences, such as landslides or landslides, can make traffic difficult and slow down necessary actions immediately after an earthquake (rescue and evacuation, clearing of rubble, inspection of building damage, etc.);
- Damage or demolition of buildings that are critical points of transport infrastructure, especially bridges, overpasses, retaining walls, etc. can disrupt important traffic flows;
- Damage to industrial facilities at direct costs due to damage to buildings and equipment may include additional consequences for the employed population and the economy as a whole, and in some cases long-term consequences due to potential environmental hazards;
- Interruptions in the telecommunications network due to damage to the population and emergency services can make communication difficult, and damage to the power network and utility infrastructure can slow down the work of emergency services and increase the feeling of insecurity of the population;
- The risk of damage to hospitals and health centres with appropriate medical equipment can further endanger the most vulnerable population and make it difficult to provide sufficient capacity to care for the injured;
- Damage to public social facilities such as theatres, museums and sports facilities can endanger the safety of large numbers of people and in the long run affect the normal course of social activities;
- Particular attention should be paid to damage to kindergartens, schools and higher education institutions, and damage to religious buildings and cultural and historical heritage can lead to irreparable losses and further demoralize the population;
- In case of damage to buildings in which state administration activities take place, there is a danger of stagnation in the state administration and disturbance of political stability, and the safety and availability of emergency services, including fire and police, are of special importance.

Seismic risk map for the Republic of Croatia is shown in Fig. 6.

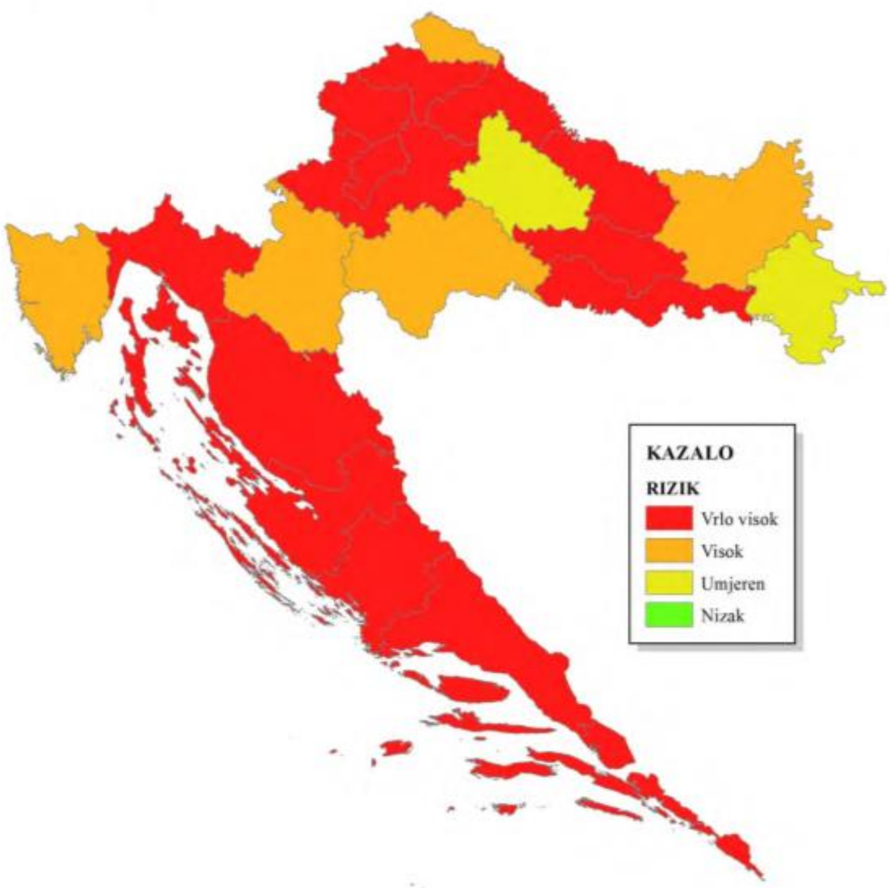


Fig. 6. Seismic risk map for Republic of Croatia [7]

4.2.2 Disaster Risk Assessment for the Republic of Croatia (2018)

According to the Law on civil protection system (NN 82/15 and 118/18) [19], assessments must be updated every three years or more often when necessary. The updated risk assessment [8] is based on the risk assessment study conducted in 2015 [7]. In this updated document, the assessment of exposure and vulnerabilities has been improved.

Seismic hazard was defined according to the mentioned map valid for the Republic of Croatia for horizontal peak ground acceleration with return periods of 475 and 95 years. The influence of local soil conditions was not taken into account.

The assessment process was improved on the basis of selection of each building or group of buildings with similar properties and assignment of the corresponding load-bearing system. At the level of individual local districts, each type of structural system was associated with the number of residents.

The number of casualties is estimated on the expected number of heavily damaged and collapsed buildings.

The vulnerability analyses of the exposed buildings and evaluation of the respective economic losses were carried out using vulnerability and fragility curves [27]. A set of curves was associated with each individual structural type. The procedure was conducted according to the macroseismic method in accordance with the RISK-UE project [28]. The damage was determined according to the EMS-98 scale with five damage states [26], while the vulnerability of buildings was expressed by vulnerability index [29].

Damage factors, which represents a ratio of the cost of repair for each damage state and the total replacement cost of the building, were assumed in order to associate the economic losses to the expected structural damage. Vulnerability curves for characteristic building types were obtained by convolving building fragility curves with the cumulative cost of a given damage state, to estimate economic losses and fatalities for seismic scenarios in Zagreb. Total economic losses were calculated for each local board with respect to the structural systems and the number buildings. The estimate of fatalities was also made for each local board and was determined depending on the number of people residing in the collapsed buildings during the earthquake action.

Analysis of the *civil protection system* is included in this document. In the context of assessing community resilience to the consequences of disasters, an analysis of the state of preparedness of the civil protection system is important. The results of this analysis are used in the process of analysing each individual and total risk, as well as for the development of specific projects to reduce vulnerability and determine priorities in the development of the capacity of the civil protection system. In this sense, the Assessment is used to determine the resilience of the community to the harmful effects of various threats, but also for the purpose of detecting weak links in the capacity to respond to disasters.

With the conducted analysis, the most important parts of the system are analysed, as well as the level of readiness for response of the system as a whole, both at the local and regional and at the state level. The components of the system that are the subject of this analysis are prevention and response.

Prevention

Within the area of prevention, the most important components were analysed, such as documents / bases from the competences of central state administration bodies and local self-government. Following these documents, measures and activities that are operatively implemented in response capacities are determined: adopted strategies, regulations / norms, action plans of the civil protection system, harmonization of public policies on disaster risk reduction, development of early warning system, state of risk awareness, state of spatial planning and legalization of buildings, assessment of the fiscal situation and its perspectives.

Strategies, normative regulations, plans: In all major sectors, such as spatial planning and construction, environmental protection, economy, water management, transport and maritime affairs, agriculture and health, sectoral strategies were adopted as well as related implementation / action programs and plans for their implementation. The Croatian Disaster Risk Reduction Platform, as a coordinating body, is a possible response to the perceived lack of coordination between sectoral strategies as well as an opportunity to develop certain administrative capacities in central government bodies to participate in disaster risk reduction at the national level. According to Civil protection law (2015), the civil protection system is an organizational framework for disaster response within which specific responsibilities are defined at all levels of the system.

Early warning system: The early warning system is based on national systematic forecasts and assessments by the competent authorities and data obtained from international and other sources. There is no early warning system for earthquakes.

State of awareness of contemporary risks: The Ministry of the Interior is the initiator of the program of raising citizens' awareness on the disaster risk reduction, with priority given to the youngest categories of preschool and primary school age. The Ministry encourages the incorporation of disaster risk reduction content into all relevant sectoral strategies, laws and regulations and works to increase the interconnectedness and coherence of their content. Awareness-raising activities on the topic of risk reduction are still not carried out systematically, and the contents are not presented within the regular school curriculum, but the implementation of ongoing awareness-raising projects will further contribute to positive developments in this area. Croatian platforms for disaster risk reduction is important for awareness-raising activities. The Platform proposes solution adopted by the Government of the Republic of Croatia and incorporated into sectoral strategies. In this way institutional awareness of risks and the need to implement risk management activities as a priority area to ensure the security of the state are improved. These activities also increase the awareness of citizens.

Spatial planning and legalization of buildings: The Republic of Croatia is pursuing public policies to protect this resource, but despite this, challenges have emerged that need to be addressed. This is evident in partly devastated urban structures as a result of illegal construction, water pollution, uncontrolled forest exploitation, soil degradation, unregulated municipal waste landfills and identified cases of uncontrolled hazardous waste disposal, poor land management and inappropriate land use conversions. One of the identified challenges, in the context of this project, is the inconsistency in the application of regulations in the field of construction, especially in the segment of application of anti-seismic building regulations because a significant part of urban and tourist centres and cultural assets is located in a seismically high risk area. All this affects the level of risk in certain areas, especially since, in the absence of detailed research on compliance with building regulations, the risk assessment mostly uses data on the year of construction of houses with the assumption that they were built in accordance with applicable regulations. Since the entry into force of the Act on the Treatment of Illegally Constructed Buildings (NN 86/12, 143/13, 65/17 and 14/19), more than 800,000 requests for legalization have been received, and some of these buildings are located in high-risk areas such as floodplains, landslides and in the vicinity of plants with hazardous substances as well as landfills. This opened up the problem of security of people and buildings in those locations. This should be taken into account when making local vulnerability assessments. However, after June 30, 2013, no building can be built without a building permit, which is important for the safety of at least newly built buildings.

Financing: The financing of the system is carried out at the state and local levels. Most of the funds spent are used to finance operational capacities and disaster response activities, while a small percentage of funds are used for preventive action. In most local governments, civil protection does not represent a clearly visible need and investments in its development do not represent priorities in relation to other public expenditures.

Response area

Analysing the response area, the state of readiness of the responsible and management capacities of the system and the operational capacities of the civil protection system for disaster response is determined. The state of readiness is analysed by: structure, composition and size of capacity; areas of operational competence; personal and material structure; state of manpower, command of forces, state of training, exercise, equipment, time of mobilization and readiness for operational action; the state of mobility of forces and connections; possibilities of material support to operational capacities during the implementation of civil protection measures in disasters as well as other needs of forces until demobilization, the state of databases and other bases for the needs of civil protection planning and conclusions on the state of the civil protection system in the Republic of Croatia.

Ready for responsible and management capacities of the civil protection system: Executive bodies as participants in the civil protection system are responsible for implementing administrative and planning measures for the organization, development and provision of conditions for operational action in disasters, proposing regulations, making assessments and plans, implementing preventive measures and activities with emphasis on vulnerability reduction policies, holder of all functions of the system, its organization, financing and supervision of the implementation of regulations.

Readiness of operational capacities of the civil protection system: They are composed of the capacities and teams of the fire brigade, the Red Cross, the Croatian Mountain Rescue Service, legal entities in state and private ownership in the areas of construction, transport, accommodation, inventories and other areas of importance. In order to eliminate the consequences of disasters, civil protection units are being established at the levels of all local and regional self-governments and at the state level, which complement the capacities of the basic operational forces of the civil protection system.

State of databases and basis for civil protection planning: Databases for the needs of the civil protection system exist, but their use, records and data collection need to be regulated in a systematic way to facilitate the preparation of analyses for the needs before and after disasters and to ensure the reliability and comparability of risk assessment results. In this sense, there is a noticeable lack of information on available computer tools, which is accompanied by a lack of the necessary professional staff to use the tools, at the state level to analyse each of the risks. The Geographic Information System (GIS) is being developed by the Ministry of the Interior for the needs of the civil protection system. Until now, the Republic of Croatia has not prescribed a single database on all consequences of extraordinary events, but only collects data on the financial side of damages for the purposes of conducting procedures for seeking assistance from the local community budget and the state solidarity fund established for that purpose. This situation most directly affects the uncertainty of the results obtained by the risk analysis process and the recommendation, as well as good practice of EU countries, is to establish a single database on all damages and vulnerabilities available to all entities in the risk assessment process at national, local and regional level.

Mobility and connections: Participants in the civil protection system from the state level are hierarchically functionally connected with participants at the local level. The collection and exchange of information between the levels of the system takes place within special communication and information systems on the regular use of individual participants in the civil protection system and through a single communication and information system of the 112 centres.

In the document, the assessment of the state of readiness of the civil protection system was performed for all the above components, where the readiness was assessed with 4 categories: very low, low, high, very high.

4.3 Disaster Risk Assessment for the Split-Dalmatia County

In accordance to Croatian national laws, regulations and guidelines Split-Dalmatia County was made document *Risk assessment of major accidents for the area of Split-Dalmatia County* (2021) [9]. In order to be comparable to the *Disaster Risk Assessment for the Republic of Croatia* [8], and in accordance with the *European Commission's Risk Assessment and Mapping Guidelines for Disaster Management* (EC SEC (2010) [21], the assessment is based on the same scenarios, probability and criteria.

The assessment consist of the following chapters: basic characteristics of the area, identification of threats-register of all known risks, simple risk scenarios describing the event with the worst possible consequences, probability / frequency tables, criteria for assessing the impact of threats on categories of social values to human life and health, economy and social stability and politics, simple risk scenario matrices and for each of the criteria separately, matrices with compared risks in the area of Split-Dalmatia County, i.e. local self-government units, analysis of the civil protection system, risk evaluation and finally risk mapping.

The earthquake was identified as a threat with possible consequences on the loss of human lives, demolition of buildings and damage to infrastructure elements. Within the impact on social values, the impact on human life and health, the economy, social stability and politics is evaluated. Preventive measures include protection measures in urban plans and construction. Response measures are aimed at organizing the operational forces of the civil protection system, the health care system and the provision of capacity for care and nutrition.

The area of the County covered by seismic areas of intensity VII °, VIII ° and IX ° according to the MSK scale, which can cause material damage and human casualties. Zone IX degree of the MSK scale covers the area of mountain Biokovo, localities Makarska -Imotski- Sinj in a total area of about 4000 km^2. Zone VIII of the MSK scale covers numerous localities of the central Dalmatian islands: Vis, Hvar, Brač, Šolta, the Split agglomeration (Kaštela City belongs to this agglomeration) and the area of Sinj. Zone VII of the MSK scale covers other areas of the county.

The consequences of the earthquake were analysed on the basis of the earthquake scenario in the Split-Dalmatia County caused by the earthquake at the level of the return period harmonized with the regulations for the design of the seismic hazard (95 years for the most probable event and 475 years for event with the worst possible consequences). The most visible effects of the earthquake would be in individual historical units in the County, such as Split (Diocletian's Palace), Trogir (historical core), which are centuries-old and millennial old urban areas that would be destroyed or partially destroyed. Possible devastating consequences on critical infrastructure elements (water supply, roads, energy water supply, telecommunications, sewerage system, etc.) were analysed. Possible consequences for the population depend on the population density in individual settlements and residential buildings (type of construction and building materials used in construction).

When considering earthquakes as a natural disaster in the Split-Dalmatia County, the event with the worst possible consequences, an earthquake of intensity IX˚ MSK scale, will be taken into account. Knowing the time of construction of a particular group of buildings, a rough conclusion was made about their seismic resistance. The effects and consequences of the effects of earthquakes of intensity VII°, VIII° and IX° MSK scale in the area of Split-Dalmatia County on the infrastructure were analysed.

Damage to the building stock is expressed through the percentage of destruction of the buildings in relation to the initial condition (through the number of buildings expressed as a percentage that includes the total number of buildings). The consequences of earthquake the buildings, on industrial facilities, estimation of the amount of construction waste and consequences that earthquakes can cause on the population expressed in the number of dead and injured are analysed.

Risk map for the County (Fig. 7) was defined and the whole territory was divided into 4 categories of risks: very high, high, moderate and low.

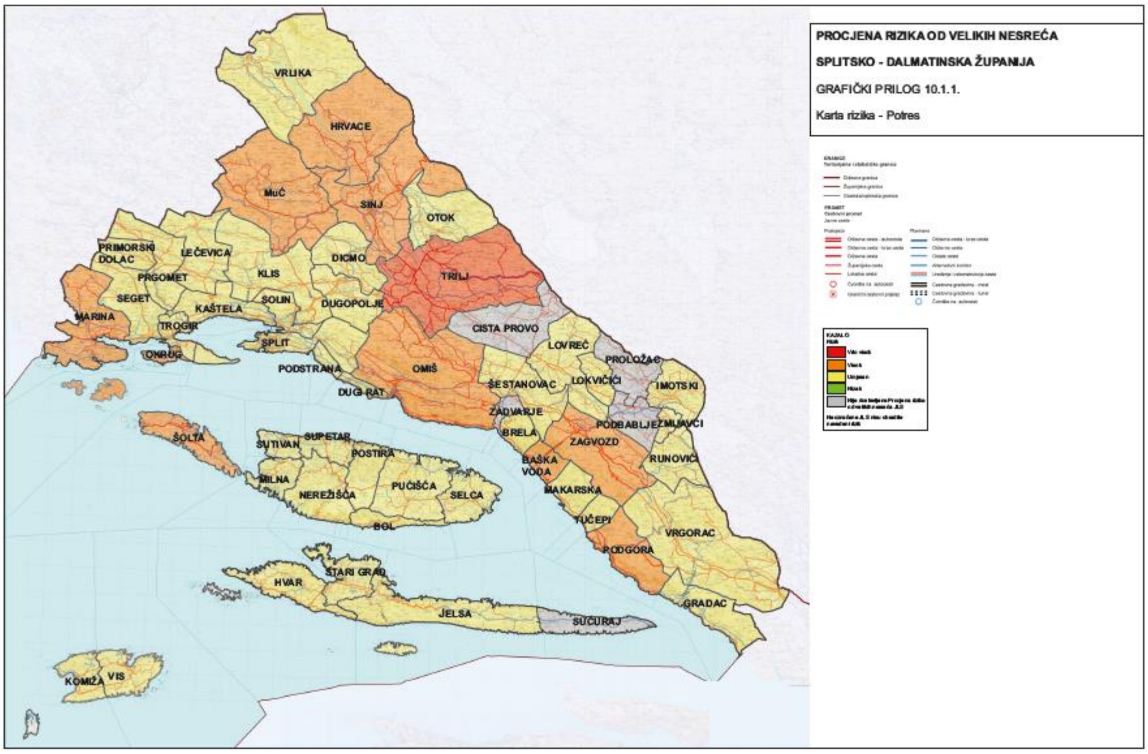


Fig. 7. Seismic risk map for Split-Dalmatia County, *Disaster Risk Assessment for the Split-Dalmatia County*, 2021.

Analysis of the *civil protection system* is elaborated as follows.

Prevention

Strategies, normative regulations, plans: The readiness of the civil protection system, assessed on the basis of the development of sectoral strategies, normative regulation and the development of assessments and plans relevant to the civil protection system, is assessed as high.

Early warning system: The County Prefect (or the Chief of the Civil Protection Headquarters of the Split-Dalmatia County) is informed in case of danger by the County Centre 112, the Central Body in charge of civil protection and public sector institutions.

State of awareness of contemporary risks: The readiness of the civil protection system assessed on the basis of the state of awareness of the managing and responsible bodies in the civil protection system about modern risks and optimal treatment in the implementation of obligations within their competences in order to mitigate the consequences of threats is low.

Spatial planning and legalization of buildings: Readiness of the civil protection system based on the assessment of the state of spatial planning, development of spatial and urban development plans, planned land use as an important national resource, the impact of legalization of illegally constructed buildings on community safety and application of special construction preventive measures / standards in procedures in the project documentation and in the procedures for issuing location and construction permits was assessed as high.

Financing: The readiness of the civil protection system based on assessments of the fiscal situation and its perspective, especially for the reallocation of part of the funds used to respond to the needs of financing the implementation of preventive measures, is assessed as high.

State of databases and basis for civil protection planning: The Split-Dalmatia County has partially established the records of members of the operational forces of the civil protection system. Therefore, the readiness of the civil protection system is estimated to be low based on the database.

Response area

The readiness of responsible and management capacities and readiness of operational capacities of the civil protection system are assessed as high. State of mobility of operational capacities of the civil protection system and state of communication capacities are assessed as low.

4.4. Disaster Risk Assessment for City of Kaštela and other relevant documents

4.4.1 Disaster Risk Assessment for City of Kaštela and other relevant documents

City of Kaštela has several documents governing the area of risk management:

1. Risk assessment of major accidents for the City of Kaštela, 2021 [10]
2. Action plan in the field of natural disasters for 2020 [30]

3. Protection and rescue plan [31]
4. Plan of urban measures for protection against natural disasters and war dangers (within Amendments to the spatial plan of the City of Kaštela) [31]

The *Risk assessment of major accidents for the City of Kaštela*, 2021 [10], is a document that follows the methodology for defining risk set out in the similar documents of the Republic of Croatia [8] and the Split-Dalmatia County [9].

With regard to the danger of earthquakes, the area of the City of Kaštela should be treated as an endangered area VIII ° of earthquake intensity according to the MSK scale, which can cause significant material damage and human casualties. The frequency and intensity of earthquakes for the areas around the Town of Kaštela from 1879 to 2003 were analysed. In the area of the City of Kaštela in the period from 1897 to 2003, earthquakes of the following intensities were recorded: 16 earthquakes of intensity V° MSK scale, 1 earthquake VI° MSK scale and 2 earthquakes VII° MSK. In the vicinity of the City of Kaštela in the mentioned period, earthquakes of different intensities were recorded, which were felt in the area of the City, but had no significant recorded consequences. The highest number of earthquakes was felt in the settlements of Prgomet, Trogir and the cities of Split and Solin, mostly V ° (16-19 times), VI ° (1-7 times) and VII ° (1-2 times), and recorded earthquakes VIII ° MSK the scales are in the cities of Sinj (2 times) and Trilj (2 times).

Scenarios for the return periods of 95 years for the most probable event and 475 years for event with the worst possible consequences were selected for the analysis of the consequences of the earthquake.

The City of Kaštela is one of the most densely populated local self-government units in the Republic of Croatia because, according to the last census from 2011, there were 38.667 inhabitants in the City, and the area of the City is 56.9 km^2.

Possible human casualties are primarily the result of the expected destruction of residential buildings and buildings where many people stay. In addition, there would be unrest and panic among the population, and additional human losses are possible. Family houses predominate in the area of the City of Kaštela. The document lists the buildings where a large number of people live. Between them, the largest are the primary and secondary schools. Tourist capacities were filled only during the tourist season, so they were not analysed.

Awareness of the possible danger due to the effects of earthquakes on existing buildings and empirical data have significantly affected the development and frequent changes in regulations for the design of structures. In recent years, new Croatian standards have been applied based on European standards for the design of seismic resistance (Eurocode 8), and based on modern research, the requirements that buildings must meet in order to achieve an acceptable level of safety are significantly tightened.

Considering the earthquake as a natural disaster in the City of Kaštela, the event with the worst possible consequences was taken into account (earthquake of intensity VIII° MSK scale), which can cause great material damage and consequences for the population.

The damage prediction from a hypothetical earthquake in the City of Kaštela was made for an earthquake of magnitude VIII MSK scale with epicentre in Kaštel Sućurac, acceleration equal in the whole area, earthquake duration up to 15 seconds and ignoring differences in geotechnical soil composition and possible occurrence of dynamic soil instability liquefaction.

The method of building construction was analysed. In the City of Kaštela, houses are mostly built of stone and lime binder. In the central parts of the settlement, the construction is denser (groups of 5 - 10 compacted houses between which there is a narrow road about 3 m wide or the buildings are leaning against each other). The number of floors in the building is 1-3 floors. In the outer parts of the settlement, the construction is rarer and the buildings are not compact. Knowing the time of construction of each group of buildings, rough conclusions were made about their seismic resistance. Thus, the buildings were built until 1920 had ceiling constructions made exclusively of wooden beams. Reinforced concrete ceilings were gradually applied in the period from 1920 to 1940. From 1945 to 1964, reinforced concrete monolithic ceilings of semi-prefabricated types or constructed on site prevailed. After 1964 buildings are systematically built with horizontal and vertical confining elements. Buildings with a reinforced concrete load-bearing system began to be built after 1960.

The review of the damage to the building stock for the earthquake of the VIII degree of intensity was determined according to the category of the building. Buildings are classified into 5 categories: masonry, masonry with RC confining elements, reinforced concrete frame buildings, buildings with RC wall system, and frame buildings with AB load-bearing walls. The damages were classified into 6 categories and construction damage and number of damaged flats were estimated.

The effects and consequences of the earthquake intensity VIII° MSK scale in the City of Kaštela on the elements of critical infrastructure have been analysed.

The consequences for industrial facilities were also analysed. It was assessed that the economic zones and other facilities were separated from each other at the east part of the city. There are no social facilities nearby, except for a few family facilities, which means that they are not dangerous to each other. There is an airport in the western part of the city and it is expected that an earthquake of intensity VIII° of the MSK scale may damage the facilities in the airport.

It is estimated that a total of 541 people would be injured and a total of 60 people would be killed in the earthquake of intensity VIII° MSK scale in the City. During the summer season, due to the large number of tourists, that number would be even higher.

The overall earthquake hazard assessment for the worst case scenario compliant with the regulations for earthquake resistance design (earthquake with a return period T = 475 years) found that the probability of such an event is extremely low, but its consequences can be significant (Fig. 8). The catastrophic consequences for human life and health can be expected.

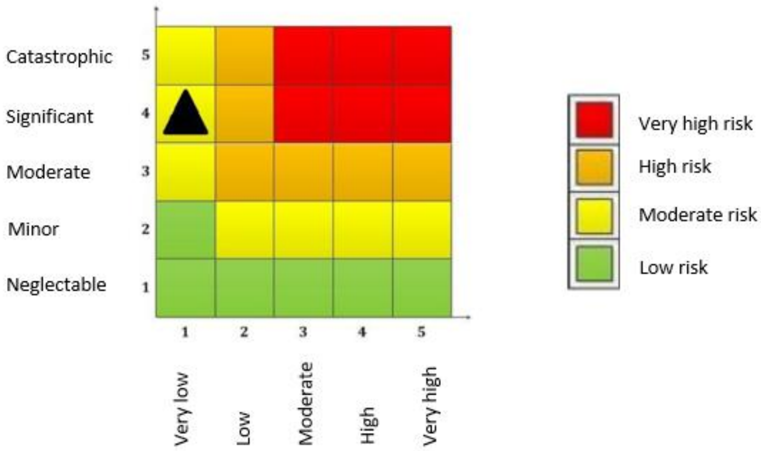


Fig. 8. Seismic risk matrix, Risk assessment of major accidents for the City of Kaštela, 2021.

Analysis of the *civil protection system* is elaborated as follows.

Prevention

Strategies, normative regulations, plans: The readiness of the civil protection system, assessed on the basis of the development of sectoral strategies, normative regulation and the development of assessments and plans relevant to the civil protection system, is assessed as high.

Early warning system: Warning of mayors in case of impending and imminent danger is performed by the County Centre 112, MIA Split Civil Protection Service, State Hydrometeorological Institute (DHMZ), Croatian Water, Police Administration, State Institute for Radiological and Nuclear Safety, legal entities that protect and rescue engaged in their own activities, economic entities users of hazardous substances, individuals, residents of the City. The readiness of the civil protection system based on the development of early warning, information exchange and their use to raise the readiness of the civil protection system through preparations for the implementation of measures and activities to reduce the consequences of imminent and emerging threats is high.

State of awareness of contemporary risks: The state of awareness about the risks of individuals and members of vulnerable groups is insufficiently developed, so it is necessary to develop communication and operational solutions tailored to the needs of members of vulnerable groups in order to bring the implementation of measures according to early warning information to a satisfactory level. The readiness of the civil protection system based on the state of awareness of the managing and responsible bodies in the civil protection system about modern risks and optimal treatment in order to reduce the consequences of threats is assessed as high.

Spatial planning and legalization of buildings: The City of Kaštela has prepared a number of planning documents in the field of spatial planning. Due to the lack of submitted data on the number of received and resolved requests for legalization of buildings in the City of Kaštela, the readiness of the civil protection system based on the assessment of spatial planning, development of spatial and urban development plans, planned land use as an important national resource, the safety of communities and the application of special construction preventive measures / standards in the procedures of incorporating requirements and special conditions in the project documentation and in the procedures of issuing location and construction permits was assessed as low.

Financing: The readiness of the civil protection system based on assessments of the fiscal situation and its perspective, especially for the reallocation of part of the funds used to respond to the needs of financing the implementation of preventive measures, is assessed as high.

State of databases and basis for civil protection planning: The City of Kaštela has established the necessary records of members of the operational forces of the civil protection system, and the readiness of the civil protection system is assessed as high on the basis of the database.

Response area

The readiness of responsible and management capacities is estimated as high. The readiness of operational capacities of the civil protection system are assessed as low. State of mobility of operational capacities of the civil protection system and state of communication capacities are assessed as high.

4.4.2 Action plan in the field of natural disasters for 2020 – City of Kaštela

Action plan in the field of natural disasters for 2020 [30] regulates the criteria and authorities for declaring a natural disaster, assessing the damage e from a natural disaster, granting assistance for mitigation and partial elimination of the consequences of natural disasters in the local self-government, register of damages from natural disasters and other issues related to granting aid for mitigation and partial elimination of the consequences of natural disasters.

The action plan contains:

- list of measures and holders of measures in the event of a natural disaster;
- assessments of insurance of equipment and other means for protection and prevention of damage to property, economic functions and suffering of the population;
- all other measures that include cooperation with the competent bodies from the Act and / or other bodies, scientific institutions and experts in the field of natural disasters

For the earthquake intensity VIII° MSK scale, the event with the worst possible consequences, expected material damage and consequences for the population have been analysed.

In terms of the impact of earthquakes on critical infrastructure, it has been concluded that:

- Due to damage or rupture of transmission lines and damage to transformer stations and transformers, there would be no supply of electricity or it would be difficult, which would cause the interruption of the normal functioning of the community;

- Telecommunications facilities may suffer minor damage (regional exchanges, repeaters, overhead telephone poles), but interruptions would be short-lived and would take several hours to rectify;

- Access to the settlements of the City of Kaštela requires immediate - priority clearing of the following streets: Jadranska magistrala (D8), Kaštelanska cesta (Ž 6137) and transverse routes connecting the Zagorje part with the coastal, Ž 6091 Unešić-Prgomet-Plano and Ž 6098 (Drniš) Kljaci- Lečevica-Kaštel Stari; the runway of the airport "Resnik", and the railway Knin - Perkovic - Solin - Split. Where possible, alternative routes should be built to allow the arrival of saviors;

- The collapse of health facilities is possible;

- Problems with drinking water supply are possible due to interruption of electricity production / distribution;

- The cultural monuments and other cultural goods and objects of archaeological sites are damaged, collapsed or completely destroyed. There is a special danger when destroying sacral buildings during the service of Mass or sightseeing. In that case, it is realistic to expect, in addition to damage to the sacral building, sacrifices among the faithful.

It is expected that damage to buildings will primarily affect older buildings, so that the danger to the population residing in public buildings of newer construction is minimized.

The document defines a list of civil protection measures and the holder of measures in the event of an earthquake. In the implementation of earthquake protection measures, the problem is also the lack of reliable parameters:

- there are no systematized databases on the typology of construction;

- a large number of illegally constructed buildings (without valid documentation) which include unfavourable interventions (e.g. demolition of load-bearing walls for shop windows) in the load-bearing structure, i.e. change of essential requirements for the building;

- uncertainty in the assessment of the vulnerability of certain buildings due to the difference in knowledge about old buildings in relation to buildings designed in accordance with modern regulations;

- there are no data on the construction of buildings, materials used, possible construction errors, subsequent repairs;

- there are no data on the effect of earthquakes on buildings (neighbourhoods) throughout history and possible consequences;

- buildings are usually designed for a lifespan of 50 years which is exceeded (material degradation) in most of the existing housing stock.

Of particular importance are public information systems that must not be interrupted

4.4.3 Protection and rescue plan

Protection and rescue plans [31] were adopted to determine the organization, activation and operation of protection and rescue systems, tasks and competencies, human forces and necessary material and technical resources, and measures and procedures for the implementation of protection and rescue in disasters and major accidents. Protection and rescue plans are made on the basis of an assessment of the threat from certain types of threats and risks that can cause a catastrophe and a major accident.

The plan consists of: (1) warning, (2) readiness, mobilization (activation) and increase of operational forces, and (3) protection and rescue measures.

In the event of an earthquake, the following measures are defined: organization of clearing of ruins and rescue of buried persons, tasks of civil protection forces for rescue from ruins, organization of establishing the function of critical infrastructure facilities, organization of fire extinguishing, regulation of traffic and insurance during interventions, material disposal sites, organization of first aid and medical care, organization veterinary assistance, organization of care, organization of evacuation, organization of human rehabilitation and identification of the dead, organization of hygienic and epidemiological protection, organization of food and drinking water insurance, organization of receiving assistance, organization of field rehabilitation and tasks of protection and rescue entities.

4.4.4 Plan of urban measures for protection against natural disasters and war dangers (within Amendments to the spatial plan of the City of Kaštela) [32]

This document defines urban measures in accordance with the *Requirements for protection and rescue in spatial planning documents*, which are an integral part of the *Assessment of the vulnerability of the population, material and cultural assets and the environment from disasters and major disasters for the City of Kaštela* [33] .

Considering that the entire area of the town of Kaštela belongs to the VIII degree of earthquake intensity according to the MSK scale, such an earthquake would severely damage about a quarter of houses, demolish some houses, and many would be uninhabitable. Cracks in wet soil and on steep slopes could be a particular problem.

In accordance with the above, in the process of planning, preparation and implementation of measures for protection and rescue of people and material goods, it is necessary to take into account the types of buildings, possible degrees of damage and the expected quantitative consequences.

The design and construction of new buildings must be carried out in accordance with existing earthquake hazard maps in the absence of microzonation data. If construction is performed next to already constructed facilities for which there is local microzoning, such data should be used in the future construction design. In particular, an analysis of the impact of earthquakes on vital buildings and civil engineering structures that are not built according to modern regulations and standards of earthquake construction should be performed.

The measures to be provided in spatial planning are defined in order to meet the requirements of the ordinance on protection measures and natural disasters:

- Mutual distance between residential and commercial buildings must not be less than the height of the roof ridge of a higher building, but not less than $H_1/2+H_2/2+5m$;
- Only open blocks with two openings whose width must not be less than $H_1/2+H_2/2+5m$;
- Unbuilt areas for shelter and evacuation must be away from neighboring buildings at least for H / 2, and the size of the area is not less than the number of inhabitants / 4 in m2
- In settlement and between settlements, it is necessary to ensure unimpeded passage of emergency services
- The distance of buildings from the edge of the public traffic area must not be less than H/2
- The distance of buildings from the edge of the pavement of the main and regional road must not be less than H
- Conditions for arranging the space for a building plot must include the degree of seismicity of the area for social infrastructure buildings, sports-recreational, health and similar buildings used by a large number of different users as well as public transport areas.

Given the requirements of protection and rescue in case of earthquakes, it is required to make a map of construction zones and collapse zones with regard to the type of construction, collapse map $H_1/2+H_2/2+5m$, seismic risk maps, geological testing of soil and evacuation and assistance routes.

5 Appraisal of existing national, regional and local related document with comparison to international and EU requirements

5.1 Compliance of national documents with international and EU risk reduction platforms and directives

The Republic of Croatia, as a member of the United Nations, established *Croatian platform for reduction of disaster risk* in accordance with *Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters* [2], which defines the directions of action in the development of protection and rescue in the world for the period until 2015.

An additional encouragement to the process of disaster risk reduction in Croatia was the Sendai Framework for Disaster Risk Reduction 2015-2030 [1] in which seven global targets and four priorities for action have been defined to prevent new and reduce existing disaster risks. The basic objectives aim to reduce human casualties, direct economic losses and damage to critical infrastructure. The Framework is also focused on activity of the scientific community to quantify disaster risk parameters and scenarios with a special emphasis on regional, national and local applications

The attention of the Croatian platform for reduction of disaster risk is focused on the implementation of the five priorities: (1) ensure that disaster risk reduction policy is a national and local community priority, with a strong institutional basis for its implementation; (2) identify, assess and monitor disaster risks and develop an early warning system; (3) use knowledge, innovation and education to develop and build a security and resilience at all levels; (4) reduce existing disaster risks; and strengthen preparedness for effective disaster response. The national platform is focused much more on pre-disaster activities and significantly less on post-disaster response activities.

National Protection and Rescue Directorate of Republic of Croatia is main national body responsible for organization of actions, tasks, drills and workshops in order to build the disaster resilience on the national level. The directorate is also responsible for preparing the Disaster Risk Assessment of the Republic of Croatia, basic document for the development of disaster action plans for all entities in the protection and rescue system, from central state administration bodies to operational forces (fire brigade, CZ, legal entities dealing with protection and rescue, citizens' associations). National Protection and Rescue Directorate also serves regional units and local governments in making their vulnerability assessments.

As a member of the European Union, Croatia has adopted numerous obligations related to the disaster risk management. Main document which fulfill appropriate objectives of Directive 2012/18/EU [4] and the Decision 1313/2013/EU (Article 6) of the European Parliament and of the Council of 17 December 2013 on a Union Civil Protection Mechanism [5], is *Disaster Risk Assessment for the Republic of Croatia* firstly made in November 2015 [7], in accordance with the *Ordinance on the methodology for preparing vulnerability assessments and protection and rescue plans* (NN 30/14 and 67/14). According to the Law on Civil Protection System (NN 82/15 and 118/18), the Government of the Republic of Croatia adopts the updated document Disaster Risk Assessment for the Republic of Croatia in 2018 [8], fulfilling the *Ordinance on Guidelines for the Development of Disaster Risk and Major Accident Risk Assessments for the Republic of Croatia and Local and Regional Self-Government Units* (NN 65/2016), the *Risk Assessment and Mapping Guidelines for Disaster Management* SEC (2010) 1626, and *HRN ISO 31000 Risk Management*.

The main **strengths** can be summarized as follows:

- It can be concluded that the *Republic of Croatia has mainly enacted laws and initiated procedures that have resulted in documents contributing to disaster risk reduction*. These documents have adopted global requirements and priorities for disaster risk reduction highlighted in major international frameworks and European directives and regulations.

- Seismic risk management is systematically organized through the *Croatian platform for reduction of disaster risk* which is focused much more on pre-disaster activities and significantly less on post-disaster response activities, and through the National Protection and Rescue Directorate of Republic of Croatia who is responsible for organization of actions, tasks, drills and workshops in order to build the disaster resilience on the national level. National Protection and Rescue Directorate also serves regional units and local governments in making their vulnerability assessments.

- *Disaster Risk Assessment for the Republic of Croatia is a basic document for the development of disaster action plans* for all entities in the protection and rescue system, from central state administration bodies to operational forces (fire brigade, CZ, legal entities dealing with protection and rescue, citizens' associations). The document is updated every 3 years. Document Disaster Risk Assessment for the Republic of Croatia also analyses the civil protection system and focuses on prevention and response phases. Important part of the assessment is analysis of the weaknesses in seismic risk management. The identified weaknesses are the basis for improvements, both at the national and at regional and local levels.

- It is worth mentioned that *Croatia has adopted European standards for the design of earthquake resistant structures*, firstly in 2007 by adopting the European pre-standard (HRN ENV 1998:2007), and then in 2011 the European standard Eurocode 8 (HRN EN 1998-1:2011). The probabilistic *seismic hazard (PSHA) maps for return periods of 475 and 95 years were inserted into Croatian National Annex of current European standards for the design of earthquake resistant structures in 2011*. European standard Eurocode 8 and seismic hazard maps are very important for building the new seismic resistant structures.

The main **weaknesses** are as follows:

- Disaster Risk Assessment for the Republic of Croatia is *a basic document for the development of disaster action plans*. It is based on a very rough classification of buildings depending on the period of construction, the applied structural system and materials. It can provide a rough estimate of damage and casualties, but *it cannot be used for more accurate risk assessment and management.*

- However, *one of the main global target of Sendai framework* "Substantially reduce disaster damage to critical infrastructure and disruption of basic services, among them health and educational facilities, including through developing their resilience by 2030" *were not fulfilled*. Namely, destructive earthquakes in Zagreb and Petrinja in 2020, have shown extreme vulnerability of old hospital buildings as well as school buildings in the city centres. A lot of health and educational buildings in Croatian city centres are not resistant to the expected earthquake. *There is still no organized framework to encourage and provide funding for the evaluation of the seismic resistance of such buildings and strengthening those with insufficient seismic resistance.*

- Analyzing the non-binding documents of the Earthquake risk reduction in the European Union from 2007 and 2013 [16, 17], which highlighted the recommendations for earthquake risk reduction, we can conclude that *there are still no laws, regulations or initiatives at the state level to support the risk reduction* (evaluation of the seismic resistance of existing building and strengthening those with insufficient seismic resistance) of the following buildings and infrastructural objects: strategic and current dwelling buildings, lifelines and transportation networks, industrial facilities, monuments and buildings of high cultural value.

- It also turned out that *there is no state-organized form to involve the construction experts in the post-earthquake phase in assessing the condition of buildings*, emergency rehabilitation, etc. Such activities were realized after past earthquakes through self-organization of engineering associations and voluntary work of engineers. These activities are otherwise defined in an Article 6 of the Decision 1313/2013/EU (Article 6) of the European Parliament and of the Council of 17 December 2013 on a Union Civil Protection Mechanism as priority 4: Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction.

5.2 Compliance of regional and local documents with national strategies, laws and documents

5.2.1 Risk assessment of major accidents for the area of Split-Dalmatia County and Risk assessment of major accidents for the City of Kaštela

In accordance to Croatian national laws, regulations and guidelines Split-Dalmatia County was made Document *Risk assessment of major accidents for the area of Split-Dalmatia County* (2021) have been made in accordance to Croatian national laws, regulations and guidelines and it is comparable with the *Disaster Risk Assessment for the Republic of Croatia*. The risk assessment is also in line with the European Commission's Risk Assessment and Mapping Guidelines for Disaster Management, EC SEC (2010). The assessment is based on the same scenarios, probability/frequency tables, criteria for assessing the impact of threats on categories of social values (human life and health, economy and social stability and politics), scenario matrices, analysis of the civil protection system, risk evaluation and risk mapping.

The consequences of the earthquake were analysed on the basis of the earthquake scenario with the worst possible consequences in the Split-Dalmatia County caused by the earthquake for the return period of 475 years.

Damage to the building stock is expressed through the percentage of destruction of the buildings in relation to the initial condition. The consequences of earthquake the buildings, on industrial facilities, estimation of the amount of construction waste and consequences that earthquakes can cause on the population expressed in the number of dead and injured are analysed. The expected damage of the buildings, the number of dead and injured people and economic damage was estimated.

Risk map for the County was defined and the whole territory was divided into 4 categories of risks: very high, high, moderate and low.

Analysis of the *civil protection system* was elaborated in detail.

The *Risk assessment of major accidents for the City of Kaštela* [10], is a document that follows the methodology for defining risk set out in the *Risk assessment of major accidents for the area of Split-Dalmatia County* [9] and the *Disaster Risk Assessment for the Republic of Croatia* [8]. The main characteristics of the last two documents, are also contained in the document of the City of Kaštela.

Regarding to specificity of the area, construction and building characteristics, infrastructures and industry, and population, the analysis of the risk for the worst possible scenario (T=475 years) was perform and risk map was provide. The readiness of all components of civil protection system was analysed in detail.

The document especially highlights the problem of a large number of illegally built houses whose design and construction process have not been controlled. This issue are very important for the safety of communities. In addition, the application of special construction preventive measures / standards in the procedures of incorporating requirements and special conditions in the project documentation and in the procedures of issuing location and construction permits was assessed as low.

The main **strengths** of documents *Risk assessment of major accidents for the area of Split-Dalmatia County* and *Risk assessment of major accidents for the City of Kaštela* are summarized as follows:

- The documents are made in accordance with the Disaster Risk Assessment for the Republic of Croatia. *The documents have adopted global requirements and priorities for disaster risk reduction* highlighted in major international frameworks, European directives and regulations as well as national laws and regulations.
- Above documents are the *basis for the development of disaster action plans* for all entities in the protection and rescue system, from administration bodies to operational forces. The documents are updated every 3 years. In addition to analysis of the hazard scenarios and the impact of the earthquake in terms of the damage and social values (human life and health,

economy and social stability and politics), the documents also analyse the readiness of civil protection system with the focus on prevention and response phases.

- Important part of the assessment are analysis of the weaknesses in seismic risk management. The identified weaknesses are the basis for improvements at regional and local levels.

The main **weaknesses** are as follows:

- The assessments are based on a rough classification of buildings depending on the period of construction, the applied structural system and materials. They can provide a rough estimate of the damage and casualties which is a good basis for organization of civil protection system, but *cannot be used for more accurate risk assessment and management for the purpose of reducing risk and setting priorities in the rehabilitation*. This issue should be tackled through other regulations, plans and/or initiatives.

- *There are still no regulations or organized framework to support the risk reduction* (to encourage and provide funding for the evaluation of the seismic resistance of existing buildings and infrastructural objects and strengthening those with insufficient seismic resistance). Between them the following objects are of special importance: strategic and current dwelling buildings, lifelines and transportation networks, industrial facilities, monuments and buildings of high cultural value.

- It also turned out that *there is no organized form to involve the construction experts in the post-earthquake phase* in assessing the condition of buildings, emergency rehabilitation, etc. This is of crucial importance in the case of the destructive earthquake and should be considered.

5.2.2 Action plan in the field of natural disasters for 2020 – City of Kaštela

Action plan in the field of natural disasters for 2020 – City of Kaštela [30] regulates the criteria and authorities for declaring a natural disaster, assessing the damage from a natural disaster, granting assistance for mitigation and partial elimination of the consequences of natural disasters in the local self-government, register of damages from natural disasters and other issues related to granting aid for mitigation and partial elimination of the consequences of natural disasters.

The document defines a list of civil protection measures and the holder of measures in the event of an earthquake. In the implementation of earthquake protection measures, the document highlights the lack of reliable parameters such as:

- there *are no systematized databases on the typology of construction*;

- a *large number of illegally constructed buildings* (without valid documentation) which include unfavourable interventions (e.g. demolition of load-bearing walls for shop windows) in the load-bearing structure, i.e. change of essential requirements for the building;

- *uncertainty in the assessment of the vulnerability* of certain buildings due to the *difference in knowledge about old buildings in relation to buildings designed in accordance with modern regulations;*
- there are *no data on the construction of buildings, materials used, possible construction errors, subsequent repairs*;
- there are *no data on the effect of earthquakes on buildings* (neighbourhoods) throughout history and possible consequences;
- *buildings are usually designed for a lifespan of 50 years which is exceeded* (material degradation) in most of the existing housing stock.

Highlighted shortcomings should be taken into account in the phase of development of earthquake risk management plan.

5.2.3 Protection and rescue plan

Protection and rescue plans [31] were adopted to determine the organization, activation and operation of protection and rescue systems, tasks and competencies, human forces and necessary material and technical resources, and measures and procedures for the implementation of protection and rescue in disasters and major accidents. Protection and rescue plans are made on the basis of an assessment of the threat from certain types of threats and risks that can cause a catastrophe and a major accident. The plan consists of: (1) warning, (2) readiness, mobilization (activation) and increase of operational forces, and (3) protection and rescue measures.

This is important document which elaborates protection and rescue measures in detail. The document is aligned with *Risk assessment of major accidents for the City of Kaštela.*

5.2.4 Plan of urban measures for protection against natural disasters and war dangers (within Amendments to the spatial plan of the City of Kaštela)

This document [32] defines urban measures in accordance with the *Requirements for protection and rescue in spatial planning documents*, which are an integral part of the *Assessment of the vulnerability of the population, material and cultural assets and the environment from disasters and major disasters for the City of Kaštela*.

The measures to be provided in spatial planning are defined in order to meet the requirements of the ordinance on protection measures and natural disasters. The document is an important starting point for the development of urban plans.

6 Steps for development of seismic hazard and seismic risk maps

Brief description of the main steps in seismic vulnerability assesment of the test site [34-36] is presented as follow:

6.1 Data collection

The seismic assessment of the building in the test area requires the knowledge of their geometrical, material and structural characteristics. The methodology for data collection was organized as follows:

- Investigation of the buildings using historical documentation and archival documentation of the town of Kaštela;
- Detail survey of geometrical characteristics, architectural measurements and creation of architectural drawings (floor plans and cross sections);
- Identification of structural systems and materials by visual inspection, using archive documentation, literature and thermographic imaging in the several specific cases when, due to the non-documented reconstructions, it was not possible recognizing material and structural characteristics of the buildings;
- Characterization of the soil type by geophysical survey.

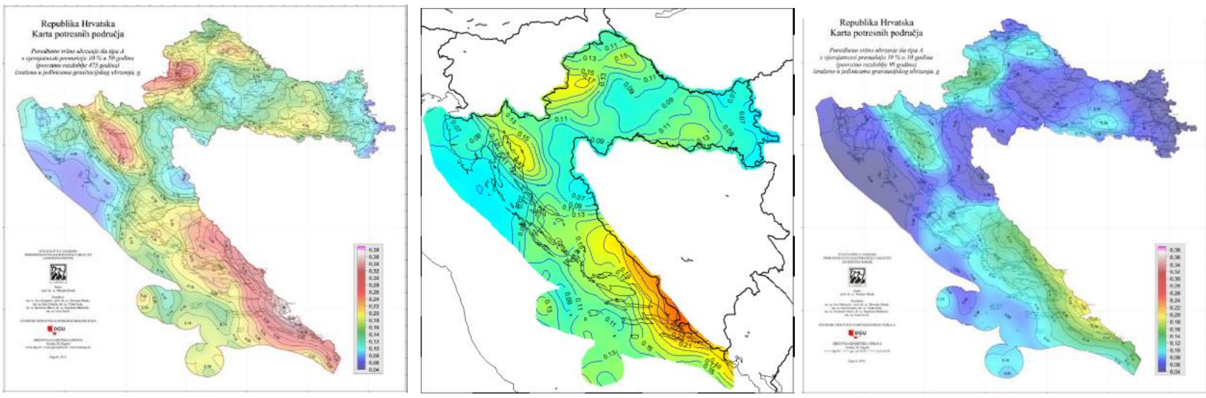
An additional help came from high-resolution geodetic maps of the test site with precise plan dimensions, from Google Map with Street View Options and also a map of the area taken in 1968 that allowed the identification of reconstructions.

Investigations of archival documentation and visual inspection were used to detect the main structural features crucial to seismic vulnerability assessment, such as: type and configuration of the structural system, texture and quality of masonry walls based on distribution of blocks and mortar joints, and their thickness, mortar quality, type of floors, floors-walls connections. Furthermore, other important aspects that were investigated are the resistance along two main horizontal directions based on estimates of the maximum resistant shear of the structure, the position and foundations, horizontal and vertical con-figurations, maximum distance among the walls, typology and weight of the roof, the presence of non-structural elements and the state of conservation. The mechanical properties of the materials (stone walls, mortar) were taken from the literature [37, 38]. A valid seismic regulation in the past was also used to identify the material properties in the cases of the reconstructions.

6.2 Seismic scenarios

Seismic hazard for Croatia can be evaluated through two maps expressed in terms of the peak horizontal ground acceleration during an earthquake, one map for a return period of 475 years, used in designing earthquake resistant buildings, and the other one for a return period of 95 years, used to check the fundamental requirements of damage states limitations [12]. The maps have been integrated in the National Annex in HRN EN 1998-1:2011 [13]. After the earthquake in Zagreb and Petrinja, maps for return period of 225 years also made. All maps are presented in Fig. 9.

In Kaštela area, the seismic hazard measured by peak ground acceleration for the soil type A is equal to a_g=0.22g, a_g=0.17g and a_g=0.11g for the return periods of 475, 225 and 95 years, respectively. In Croatia, the Type 1 response spectrum for earthquake magnitude higher than 5.5 was adopted.



(a) (b) (c)

Fig. 9. Seismic hazard maps for Republic of Croatia (PGA) for return periods of: (a) 475 [13]; (b) 225; (c) 95 years [13]

According to EN 1998-1:2011 [12] and HRN EN 1998-1:2011 [13], the soil factor S for ground types different from A, increases ordinate of elastic response spectrum. The real hazard for a certain location can be obtained by combining the peak ground acceleration for ground type A with the soil factor S describing the influence of local ground conditions on the seismic action.

The test site was investigated to classify soils according to [49]. Velocity analysis based on travel time tomography of P, S_V and S_H arrivals results with the $V_{S,30}$ map which indicate the presence of shallow hard rock [48], classified as soil type A according EN 1998-1:2011 [12]. Considering the results obtained along the three investigated lines and given the size of the test area, the seismic hazard was taken constant for all buildings in the area.

Fig. 10. Seismic hazard maps for test site Kaštel Kambelovac

Consequences of the earthquake in terms of seismic damage and seismic risk to the test area have been analyzed for three earthquake scenario. The scenario includes three levels of earthquake: 95 years for the most probable adverse event (weaker earthquake), 225 years for the earthquake of medium intensity, and 475 years for the event with the worst possible consequences (stronger earthquake). The influence of local soil conditions was taken into account.

6.3 Seismic vulnerability

Seismic vulnerabiliy of the buildings in the test area was assesed by vulnerability index method which is based on the original vulnerability index method for masonry structures developed by the Italian National Research Council and the Italian National Group for the Defense Against Earthquake (GNDT) from 1984 on-wards [40, 41]). The method consists in filling in a survey form data about 11 geometrical and structural vulnerability parameters, calculations of those parameters and finally, calculation of vulnerability index for the building. The main parameters consider type and organization of the resistant system, quality of resistant system, conventional resistance along two main horizontal directions of the building based on the estimation of the maximum re-sistant shear of the structure, position of the building and foundations, typology of floors, planimetric and elevation configuration, maximum distance among the walls, typology and weight of the roof, the presence of non-structural elements and state of conservation. For each parameter, the surveyor must judge the condition among four possibilities, from "A", corresponding to an optimal condition, to "D", meaning a bad condition. For each judgment, the method provides a numerical score. Weight coefficients are then used related to each parameter to account for the relative importance of each parameter in the global definition of vulnerability. Finally, a vulnerability index Iv is calculated in the form $I_V = \sum_i s_{vi} w_i$, where s_{vi} is numerical scores for each class and w_i is the weight of each parameter. Such a vulnerability index is then normalized in a 0-100% range. A low index means that the structure is not so vulnerable and has a high capacity under seismic action while a high index shows that the structure is vulnerable and has low seismic capacity.

Some buildings at the test area have been reconstructed and original light timber floors have been substituted with heavier reinforced-concrete slabs. Field observations of the damage states of the building heritage after the earthquakes has indeed shown that the replacement of timber floors with heavier concrete slabs, when performed on low quality masonry buildings, can substantially change the dynamic behavior of the structures, because it adds a considerable mass on the top of the building thus increasing the overall in-plane stiffness. Therefore in this project, the original vulnerability method has been improved with the modifications [42] to consider the possible substitution of the original light timber floors with heavier reinforced-concrete slabs.

The distribution of the vulnerability index of the buildings is shown in Fig. 11.

Fig. 11. Vulnerability index map for test site Kaštel Kambelovac [43]

6.4 Assessment of adverse consequences

The adverse consequences in the test site for three earthquake scenarious were presented in terms of damage and risk. Namely, the vulnerability index is not a relevant indicator of seismic risk because it doesn't give an information about the behavior of the building under a specific seismic action. Seismic risk of the buildings is here expressed by the damage caused by an earthquake of certain intensity and by a seismic safety index, here named as seismic risk index, defined as the ratio between the peak ground acceleration corresponding to the collapse of the structure and the ground acceleration for certain scenario.

The methodology for the damage and risk assessment was based on the following procedure:

- Calculation of peak ground accelerations for early damage and collapse states of the buildings by non-linear static (pushover) analysis of representative buildings;
- Development of a new damage-vulnerability-peak ground acceleration relationship which estimates the damage of the buildings under specific seismic action;
- Risk analysis in terms of seismic damage;
- Demonstration of seismic vulnerability and seismic risk by seismic vulnerability index maps, damage index and risk maps.

Important part of the project is the vulnerability curves, defined for the historical center [43] and for the whole test area (Fig. 12). They can be used to determine damage for a building with known vulnerability index and the certain intensity of seismic action represented with peak ground accelerations.

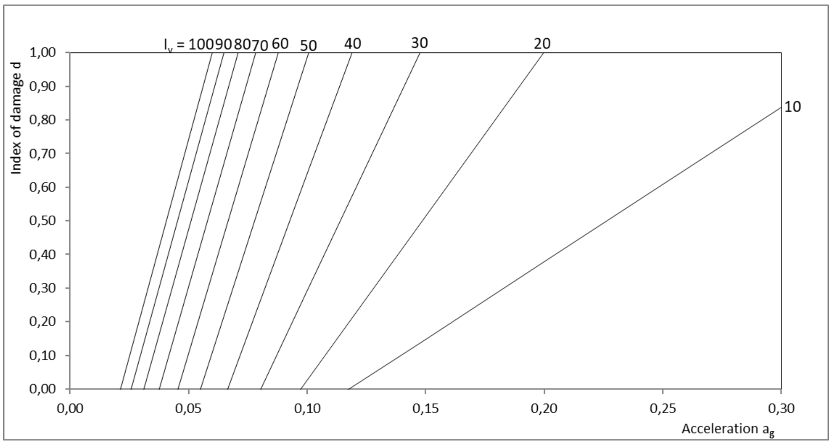


Fig. 12. Vulnerability curves: (1) for historic center of Kaštel Kambelovac; (2) for the whole test site

Given the similar characteristics of the building construction in the entire City of Kaštela, where the centers of the settlement consist of stone buildings, and outside the center are buildings and family houses mostly built of blocks with vertical and horizontal circles, future risk assessments can be performed according to 2 models:

- Simple model: Calculation of the seismic damage of the buildings based on developed vulnerability curves. The procedure implies calculation of vulnerability index for each building and damage estimation for a building for the certain intensity of seismic action using vulnerability curves;

- Complex model: Development of new damage-vulnerability-peak ground acceleration curves based on detail non-linear static (pushover) analysis for the buildings in other settlements and seismic damage and risk assessment based on the vulnerability index of the buildings and new vulnerability curves.

7 Guideliness for improving existing seismic risk management plans

Considering the weaknesses and shortcomings of existing strategies and plans in Croatia, developed methodology and main findings of the project, in this chapter, guidelines for improving existing seismic risk management plans at the test site is developed.

Guidelines for improving existing seismic risk management plans should include prevention, crisis management and post-crisis management, with particular reference to:

- guidelines within the spatial planning documentation in order to increase the seismic resistance of the buildings in the test area;
- potential construction and / or non-construction measures to increase the seismic resistance of existing endangered buildings based on the spatial distribution of vulnerabilities resulting from activity 3.3. work package 3;
- use of the results of the spatial distribution of vulnerabilities and risks in protection and rescue planning in crisis situations;
- raising the awareness of the population about the seismic risk and protocols of the behavior of the population in case of earthquakes;
- informing, protecting and rescuing the population and material goods in the event of an earthquake in the test area.

The guidelines will be elaborated through the phases of the disaster risk management cycle: mitigation, preparedness, response and recovery.

7.1 Mitigation

Mitigation activities in seismic risk management aim to prevent, eliminate or reduce the effects of the earthquakes. Mitigation measures in local seismic management plans are based on appropriate measures in national and regional development planning and on the availability of information on hazards, vulnerability and risks. The measures include application of building codes, vulnerability analyses, seismic microzoning, land use management and public education.

7.1.1 Current state of mitigation measures

Considering the current state of regulations, plans, initiatives and applied measures in the test site, we can observe the following shortcomings:

- The vulnerability and risk assessments in the City of Kaštela are based on a *rough classification of the buildings* depending on the period of construction, the applied structural system and materials. They can provide a rough estimate of the overall damage and overall casualties which are a good basis for organization of civil protection system, but *cannot be used for more* *accurate risk assessment and management for the purpose of reducing risk and setting priorities in the rehabilitation*. This issue should be tackled through the seismic risk management plan.

- *There are still no regulations or organized framework to support the risk reduction* (to encourage and provide funding for the evaluation of the seismic resistance of existing buildings and infrastructural objects and strengthening those with insufficient seismic resistance). Between them, the following objects are of special importance: *strategic and current dwelling buildings, lifelines and transportation networks, industrial facilities, monuments and buildings of high cultural value*.

- *Periodic inspections of important buildings are not performed* to determine their condition and regular maintenance.

- There are *no systematized databases* of either buildings or the typology of construction.

- *Most of the buildings have not technical documentation* and architectural plans.

- *There are no data on the construction of buildings, materials used, possible construction errors and subsequent repairs*.

- There are *buildings* at the test area that *are falling apart or have been significantly damaged*.

- *Uncertainty in the vulnerability assessment of the existing buildings* due to the difference in knowledge about old buildings in relation to buildings designed in accordance with modern regulations can lead to unreliable results of vulnerability and risk.

- A large number of *illegally constructed buildings* are placed in the test site and their *seismic resistance is questionable*. They are mostly built without design project and without construction supervision. Some of the buildings include unfavourable interventions in the load-bearing structure, i.e. change of essential requirements for the building.

- *A lifespan of 50 years was exceeded and material degradation occurred* in most of the existing housing stock.

- *There are no data on the effect of earthquakes on the buildings* (neighbourhoods) throughout history and possible consequences.

- There are *no seismic microzoning studies* of the area or geophysical investigations, except investigation performed through PMO-GATE project at the centre of Kaštel Kambelovac, which can support land-use planning or detail seismic assessment of the existing buildings.

7.1.2 Guidelines for improvement of mitigation measures

In order to reduce the risks of earthquake, the following structural and non-structural mitigation measures are proposed:

Task 1: Land use planning

Measures:

- *Micro-zonation study according to priority area*: The City of Kaštela should plan detailed geophysical investigations with the aim of microzoning the entire area. Given that these are extensive and expensive tests, the priorities in the seismic risk management plans should be defined. The results of these studies should be provided by seismic micro-zonation map.
- *Database of existing geophysical and geotechnical investigation*: In the absence of data from detailed geophysical surveys of the entire area and seismic micro-zonation map, it is advisable to create a database with the results of existing geophysical and geotechnical research in the city.
- *Provide vulnerability and risk assessment map*: The City of Kaštela should provide the vulnerability and risk map of the area analysed in this project. The seismic vulnerability and risk maps should be also planned in the future for other parts of the city.

Task 2: Retrofitting of existing structures

Measures:

- *Create a database of existing public and private structures*: It is recommended to create an electronic database of existing buildings and other structures (public and private) in which all known data, important for the assessment of seismic vulnerability, would be entered. Review of necessary data on buildings and the method of their collection will be elaborated in a seismic risk management plan.
- *Identify structures that required retrofitting*: It is recommended to identify buildings and structures that required retrofitting. Regular visual inspections of buildings should be organized to determine their condition, especially buildings of special importance like strategic buildings, lifelines and transportation networks, industrial facilities, monuments and buildings of high cultural value.
- *Prioritization of the structures:* Vulnerability and risk assessment of existing buildings at large scale in order to reduce seismic risk and set priorities in their rehabilitation should be planned at the test area. Additionally, it is recommended to assess seismic vulnerability of the buildings at the rest of the City to set priorities in the rehabilitation using an experience in seismic vulnerability assessment of the test area. Additionally, plan for monitoring and detail analysis of the most vulnerable important existing buildings, especially public and strategic buildings, should be developed in order to help in setting the priorities in rehabilitation.

- *Prepare a scheme / programme for retrofitting:* Scheme and programme for retrofitting should be developed to reduce the vulnerability of existing buildings based on the vulnerability and risk results of the buildings at the test area of this project. Retrofitting programme for other parts of the City should be planned after their vulnerability and risk assessment. It is especially important for buildings such as schools, monuments and archaeological sites, strategic buildings such as health buildings and emergency management facilities.

- *Formulate suitable financial base for retrofitting:* Local government should developed plan to fund retrofiring of vulnerable public and strategic buildings. Local government should encourage citizens to strengthen the private residential buildings with insufficient seismic resistance. It is recommended to develop measures to continuously provide funds for the rehabilitation of the most vulnerable buildings, and to provide citizens lower administrative costs when issuing permits for reconstruction.

Task 3: Removal of unsafe buildings

Measures:

- *Inventory of unsafe buildings*: The City of Kaštela the city should have a list of unsafe buildings.
- *Identify potential loss due to removal of building*: Analysis of potential economic loss due to removal of the building should be validated.
- *Formulate suitable financial base*: Financial base for removal of unsafe buildings should be provided.

Task 4: Awareness

Measure:

- *Dissemination of the earthquake risk:* The City of Kaštela should disseminate the results of the project related to earthquake risk to general public residing in the City.

Task 5: Community based disaster management

Measure:

- *Strengthening capacity of local services of the City of Kaštela:* The City of Kaštela should encourage education of employees in city services, especially those in civil engineering department, to understand local vulnerability and risk, earthquake prevention needs, preparedness and response capabilities, through seminars and workshops on seismic risk reduction.

7.2 Preparedness

Preparedness activities aim to ensure a satisfactory level of readiness to respond to emergency. Preparedness activities have to ensure that emergency services and people at risk are aware of how to react during an event. These measures include logistical readiness to deal with disasters and can be enhanced by having response mechanisms and procedures, rehearsals, developing long-term and short-term strategies, public education and building early warning systems. Preparedness measures are also focused to ensure strategic reserves of food, equipment, water, medicines and other essentials in cases of catastrophes.

7.2.1 Current state of preparedness measures

- Action on the population in order to increase the degree of awareness about seismic risk is limited. Community preparedness in the event of an earthquake is low.
- There is no organized form to involve the construction experts in the post-earthquake phase in assessing the condition of buildings, emergency rehabilitation, etc. This is of crucial importance in the case of the destructive earthquake and should be considered.

7.2.2 Guidelines for improvement of preparedness measures

The following improvement of preparedness measures in the seismic risk management plan are proposed:

Task 1: Community preparedness

Measures:

- Review earthquake preparedness in the area.
- Increase awareness of the citizens by dissemination of information about earthquake vulnerability and risk.
- Promote earthquake risk management planning.
- Take appropriate actions to enhance community preparedness through promotion and organization of education and emergency exercises/training.
- Development of protocols of population behaviour in the event of an earthquake.
- Selecting the most vulnerable groups at earthquake risk and planning activities to care for the most vulnerable groups at earthquake risk.
- Making evacuation plans based on the results of seismic vulnerability and risk assessment obtained in the project.

Task 2: Preparedness of expert teams for rapid assessment in emergency situation

Measure:

- *Training of experts for rapid assessment in emergency situation:* Organize volunteer engagement of civil engineers, electrical and mechanical engineers and other experts and provide them training to conduct rapid assessments of the state of buildings (damage state, possibility of use) as well as an assistance in emergency rehabilitation.

7.3 Response

The aim of emergency response is focused on the immediate needs of the population, such as the protection of life and property, emergency medical response, evacuation and transportation, decontamination, and the provision of food, water and shelter to victims and support the morale of the affected population. These activities are organized through civil protection system and they are not in the focus of this project. The state of the readiness of the capacities in the civil protection system in the City of Kaštela is analysed in the document *Risk assessment of major accidents for the City of Kaštela* [10]. The main conclusions of the analyses are as follows.

The readiness of responsible and management capacities is estimated as high. The readiness of operational capacities of the civil protection system are assessed as low. State of mobility of operational capacities of the civil protection system and state of communication capacities are assessed as high.

7.4 Recovery

Recovery represents short and long-term responses where the city authorities focus on clean-up, rehabilitation, reconstruction and rebuilding. Recovery measures include returning vital life-support systems to minimum operating standards, temporary housing, public information, health and safety education, reconstruction, counselling programs, and economic impact studies. Information resources and services include data collection related to rebuilding, and documentation of lessons learned.

The City of Kaštela should include recovery measures in seismic risk management plan respecting the characteristics of the area.

7.4.1 Current state of recovery measures

- Procedure and plan for post-earthquake damage assessment are not included neither in local nor in regional documents.
- There are no plans for reconstruction after the earthquake neither in local nor in regional documents.
- There are no plans for socio-economic and psychologic rehabilitation.

7.4.2 Guidelines for improvement of recovery measures

The following improvement of recovery measures in the seismic risk management plan are proposed:

- Development of plan for preliminary damage assessment during disaster phase.
- Development of plan for detail post-earthquake damage assessment to provide a clear picture of post disaster situation and to identify damage caused to different sectors.

- Development of the reconstruction strategies in the area: The strategies should include repair and restoration of damage buildings and critical infrastructures, reconstruction and relocation.
- Development of the plan for post-earthquake socio-economic and psychologic rehabilitation.

8 References

[1] Sendai Framework for Disaster Risk Reduction 2015- 2030, https://www.preventionweb.net/publications/view/43291

[2] The Hyogo Framework for Action 2005-2015: Building the Resilience of Nations and Communities to Disasters (HFA), https://www.unisdr.org/we/coordinate/hfa

[3] Yokohama Strategy and Plan of Action for a Safer World: guidelines for natural disaster prevention, preparedness and mitigation, https://www.unisdr.org/we/inform/publications/8241

[4] Directive 2012/18/EU of the European Parliament and of the Councile of 4 July 2012, https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:32012L0018&from=hr

[5] Decision 1313/2013/EU of the European Parliament and of the Council of 17 December 2013, https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:347:0924:0947:EN:PDF

[6] Croatian platform for reduction of disaster risk, https://www.preventionweb.net/english/hyogo/national/list/v.php?id=43

[7] Disaster Risk Assessment for the Republic of Croatia (Procjena rizika od katastrofa za Republiku Hrvatsku), Croatian platform for reduction of disaster risk, 2015, civilna-zastita.gov.hr/UserDocsImages/DOKUMENTI_PREBACIVANJE/PLANSKI%20DOKUMENTI%20I%20UREDBE/Procjena%20rizika%20od%20katastrofa%20za%20RH.pdf (in Croatian)

[8] Disaster Risk Assessment for the Republic of Croatia (Procjena rizika od katastrofa za Republiku Hrvatsku), Croatian platform for reduction of disaster risk, 2018, https://civilna-zastita.gov.hr/UserDocsImages/CIVILNA%20ZA%C5%A0TITA/PDF_ZA%20WEB/Procjena_rizika%20od%20katastrofa_2019.pdf (in Croatian)

[9] Risk assessment of major accidents for the area of Split-Dalmatia County (Procjena rizika od velikih nesreća za područje Splitsko-Dalmatinske županije), ALFA ATEST d.o.o., Split, March 2021. (in Croatian)

[10] Risk assessment of major accidents for the City of Kaštela (Procjena rizika od velikih nesreća za Grad Kaštela, ALFA ATEST d.o.o., Split, July 2019, https://www.kastela.hr/DesktopModules/Bring2mind/DMX/API/Entries/Download?language=hr-HR&Command=Core_Download&EntryId=3469&PortalId=0 (in Croatian)

[11] Development Strategy of Kastela City 2016. – 2020. Kastela City, 2016. (in Croatian), http://www.kastela.hr/wp-content/uploads/2016/12/T-21-Prijedlog-Strategije-razvoja-Grada-Kastela-2016-2020.pdf (in Croatian)

[12] EN 1998-1 Eurocode 8: Design of structures for earthquake resistance - Part 1: General rules, seismic actions and rules for buildings. European Committee for standardization CEN, 2004.

[13] HRN EN 1998-1:2011. Design of structures for earthquake resistance. Part 1: General rules, seismic actions and rules for buildings. Croatian Standards Institute, 2011.

[14] Dolce M, Prota A, Borzi B, da Porto F, Lagomarsino S, Magenes G, Moroni C, Penna A, Polese M, Speranza E, Verderame GM, Zuccaro G. Seismic risk assesment of residential buildings in Italy, *Bulleting of earthquake engineering*, 19, 2999–3032, 2021.

[15] Warfield C, The Disaster Management Cycle, 2008, https://www.gdrc.org/uem/disasters/1-dm_cycle.html

[16] Spence R, Lopes M, Bisch P. Plumier A, Dolce M. *Earthquake Risk Reduction in the European Union – Proposal for a European Earthquake Risk Reduction Programme – a Discusion Document*, European Association for Earthquake Engineering, February, 2007.

[17] Wenzel H, Pitilakis K, Taucer F, Wenzel F. *European Strategic Research Agenda on Earthquake Risk: Vision and Roadmap for implementation*, European Commission, Joint Research Centre, Institute for the Protection and Security of the Citizen, Luxembourg: Publications Office of the European Union, 2013, doi: 10.2788/33912.

[18] *Ordinance on the methodology for preparing vulnerability assessments and protection and rescue plans* (Pravilnik o smjernicama za izradu procjena rizika od katastrofa i velikih nesreća za područje Republike Hrvatske i jedinica lokalne i područne (regionalne) samouprave, NN 30/14, NN 67/14. (in Croatian)

[19] *Law on Civil Protection System* (Zakon o civilnoj zaštiti), NN 82/15, NN 118/18) (in Croatian).

[20] Ordinance on Guidelines for the Development of Disaster Risk and Major Accident Risk Assessments for the Republic of Croatia and Local and Regional Self-Government Units (Pravilnik o smjernicama za izradu procjena rizika od katastrofa i velikih nesreća za područje Republike Hrvatske i jedinica lokalne i područne (reionalne) samouprave, NN 65/2016 (in Croatian)

[21] *Risk Assessment and Mapping Guidelines for Disaster Management* SEC (2010) 1626, https://ec.europa.eu/echo/files/about/COMM_PDF_SEC_2010_1626_F_staff_working_document_en.pdf

[22] HRN ISO 31000 Risk Management, 2018, https://repozitorij.hzn.hr/norm/_HRN+ISO+31000%3A2018

[23] Giardini D, Woessner J, Danciu L. *European Seismic Hazard Map*, Swiss Seismological Service, ETH Zürich, Switzerland. (http://www.share-eu.org/)

[24] Državna uprava za zaštitu i spašavanje, Republika Hrvatska, Procjena ugroženosti Republike Hrvatske od prirodnih i tehničko-tehnoloških katastrofa i velikih nesreća, 2013. (http://www.duzs.hr/)

[25] Ivančić I. *Croatian Earthquake Catalogue – Presentation*, Hrvatska Seizmološka Služba, Geofizički odsjek, Prirodoslovno-matemički fakultet Sveučilišta u Zagreb, The Nato Science for Peace and Security Programme Workshop, 2011. (http://www.wbalkanseismicmaps.org/)

[26] Grunthall G. European macroseismic scale 1998 (EMS-98). Cahiers du Centre Européen de Géodynamique et Séismologie: Luxembourg, 1998, Volume 15.

[27] Atalić J, Šavor Novak M, Uroš M. Seismic risk for Croatia: overview of research activities and present assessments with guidelines for the future. Građevinar, 71 (10), 923-947, 2019.

[28] Milutinovic Z, Trendafilovski G. An advanced approach to earthquake risk scenarios with applications to different European towns - WP4: Vulnerability of current buildings, RISK-EU project, 2003.

[29] Giovinazzi S, Lagomarsino S. A Macroseismic Model for the vulnerability assessment of buildings, 13th World Conference on Earthquake Engineering, Vancouver, No. 896, 2004.

[30] Action plan in the field of natural disasters for 2020 – City of Kaštela, ALFA ATEST d.o.o., Split, November 2019. (in Croatian)

[31] Protection and rescue plan, Split-Dalmatia County, City of Kaštela, ALFA ATEST d.o.o., Split, November 2019. (in Croatian)

[32] Plan of urban measures for protection against natural disasters and war dangers (within Amndments to the spatial plan of the City of Kaštela), GISPLAN d.o.o., Split, October 2018. (in Croatian)

[33] Assessment of the vulnerability of population, material and cultural goods and the environment of the city of Kaštela), ALFA ATEST d.o.o., Split, January 2015. (in Croatian)

[34] Deliverable 3.3.1. Guidelines of the assessment procedure for earthquake vulnerability in HR test site, Part a. Building classification according to the construction period, PMO-GATE project, 2019.

[35] Deliverable 3.3.1. Guidelines of the assessment procedure for earthquake vulnerability in HR test site, Part b. Procedure for calculation of the building vulnerability according to vulnerability index method, PMO-GATE project, 2019.

[36] Deliverable 3.3.3. Determination of seismic vulnerability indexes for masonry historical buildings located in the HR test site, PMO-GATE project, 2020.

[37] Uranjek M, Žarnić R, Bokan-Bosiljkov V, Bosiljkov V. Seismic resistance of stone masonry building and effect of grouting. *Građevinar* 66(8), 715-726, 2014.

[38] Bosiljkov V, Kržan M. Results of laboratory and in-situ tests on masonry properties and tables with mechanical parameters to be adopted in numerical modelling, PERPETUATE (ECFP7 project), Deliverable D15 (www.perpetuate.eu), 2012, 225.

[39] Bohm G, Da Col F, Accaino F, Meneghini F, Schleifer A, Nikolić, Ž. Characterization of shallow sediments in an urban area (Kaštela, Croatia) by analysis of P, SV and Sh seismic velocities using a tomographic approach, Near Surface Geoscience Conference & Exhibition 2020, 30 August - 3 September 2020, Belgrade, Serbia.

[40] Benedetti D, Petrini V. Vulnerability of masonry buildings: proposal of a method of assessment (in Italian). L'industria delle Construzioni, 149 (1), 66-74, 1984.

[41] Rilevamento della vulnerabilita sismica degli edifici, Istruzioni per la compilazione della scheda di 2° livello (Muratura). Roma : GNDT - Gruppo Nazionale per la Difesa dai terremoti, 1993.

[42] Ferrini M, Melozzi A, Pagliazzi A, Scarparolo S. Rilevamento della vulnerabilita sismica degli edifici in muratura, Manuale per la compilazione della Scheda GNDT/CNR di II livello, Versione modificata dalla Regione Toscana. S.l.: Regione Toscana, Direzione Generale delle Politiche Territoriale e Ambientali, Settore - Servizio Sismico Regionale, 2003.

[43] Nikolić Ž, Runjić L, Ostojić Škomrlj N, Benvenuti E. Seismic vulnerability assessment of historical masonry buildings in Croatian coastal area. Applied Sciences, 11, 5997, 2021. https://doi.org/10.3390/app11135997