



State of the Art on European Regulations concerning fire, seismic stability, energy efficiency and environmental comfort, used as directives for preparing conservation proposals.

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PART A: Seismic Stability

A.1 Seismic intensities in Europe and in the 4 countries participating in CONSECH20

European countries are located on seismologically active plate areas of varying intensities. In order to increase knowledge and decrease the risk of a disaster, a European-Mediterranean Seismic Hazard Map (Fig. 1) was developed within the framework of the European Seismological Commission and UNESCO. This map lists the peak ground acceleration (PGA) with a chance of 10% being exceeded in 50 years, for stiff soil condition (Soil type A).

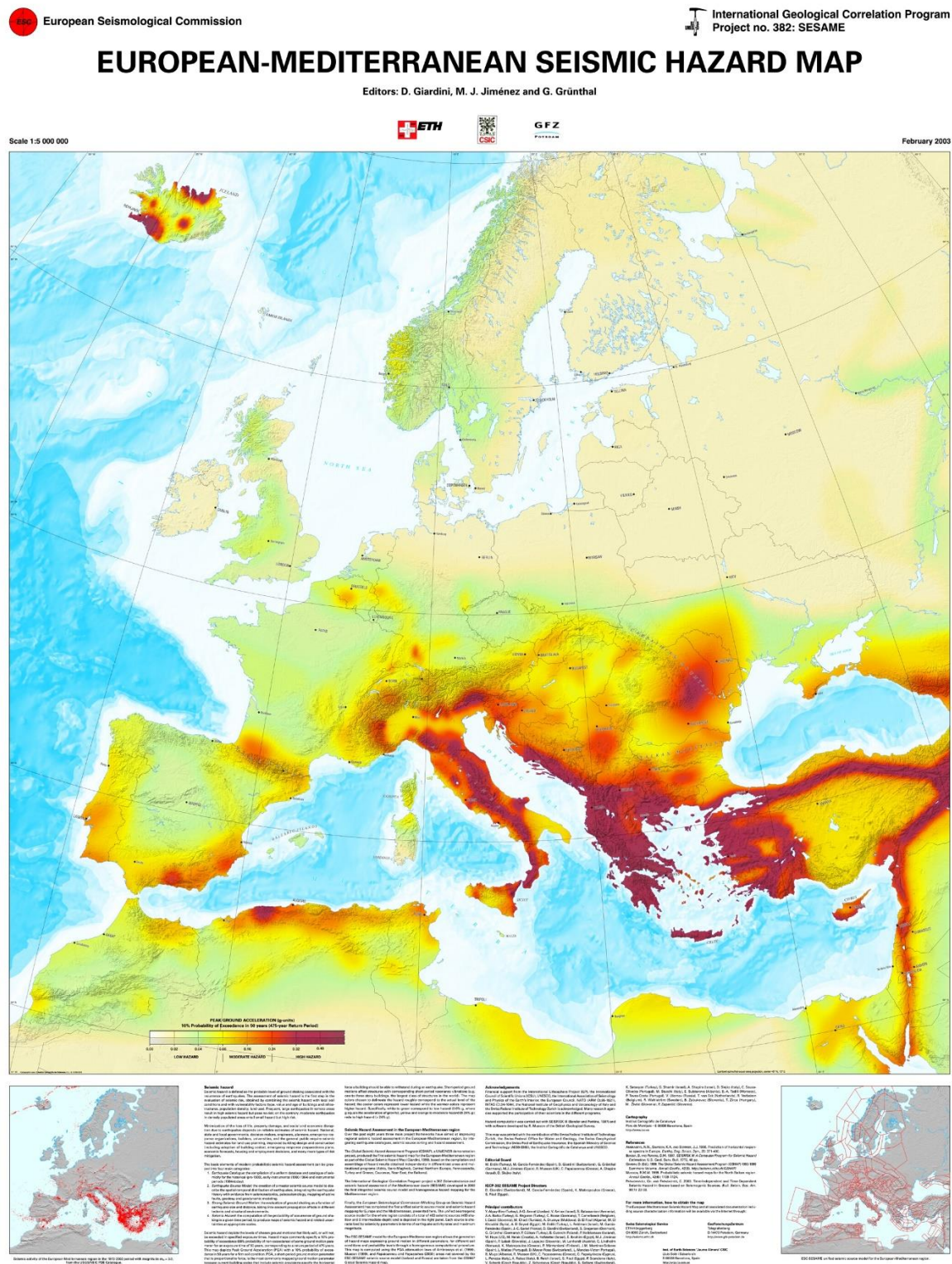


Fig. 1: European-Mediterranean Seismic Hazard Map [1]

The seismic zones and intensities (in terms of PGA) of the four countries participating in the CONSECH20 consortium are shown in Figures 2 and 3, respectively.

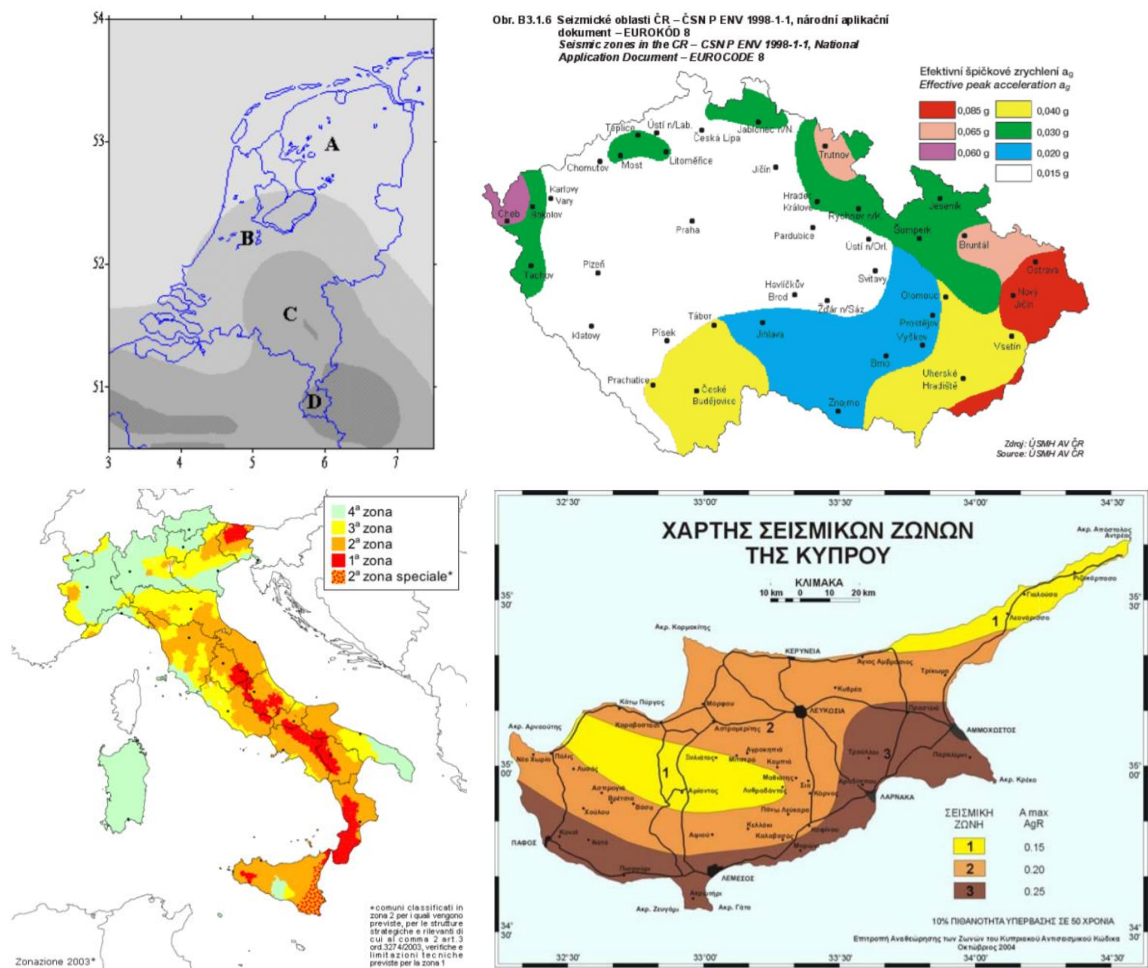


Fig. 2: Seismic zones for design purposes in the 4 countries participating in the CONSECH20 project

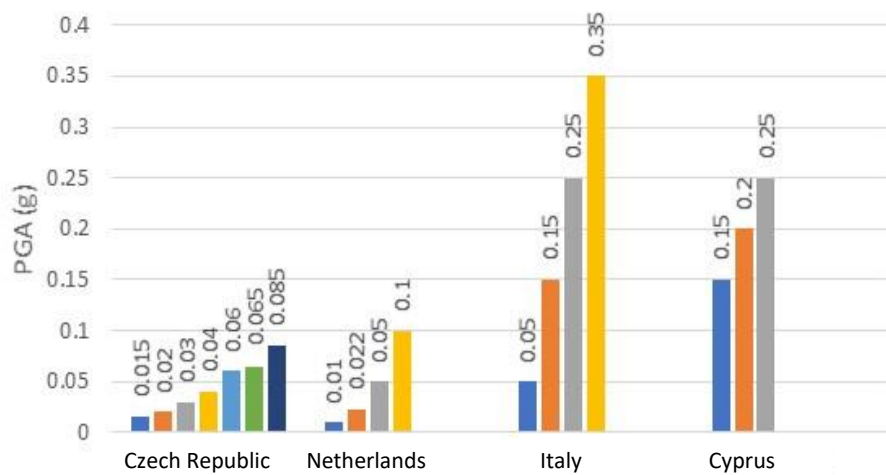


Fig. 3: Peak Ground Acceleration (PGA) for stiff soil condition (Soil type A) with 10% probability of exceedance in 50 years, relative to the respective seismic zones, in the 4 countries participating in the CONSECH20 project

A.2 Evolution of regulations concerning seismic stability

Concrete appeared in mid-19th century, and was originally connected to Joseph Monier, who patented his own construction method with iron and concrete in 1867. At that time, reinforced concrete was developed mainly by industrialists and inventors, and was subjected to closed patent systems for profit. Some of the most important patent systems of the time were Monier, Hennebique and Blanc [2].

The patent sovereignty lost its power during the period of WW II, when many academics advanced the knowledge of reinforced concrete with experimental research. Additionally, many of the aforementioned patented systems showed failures during this period, and this forced many countries to develop regulations that would ensure at least some low levels of safety for the design of concrete structures. The first relevant Codes appeared in Switzerland (1903, 1909), Prussia (1904, 1907), France (1906), the United States (1908, 1910), Italy (1907), England (1907, 1911), Denmark (1908), and Russia (1908, 1911) [2].

The first engineering recommendations for the seismic analysis of structures were introduced in Italy in 1909, following the 1908 Messina earthquake [3]. Royal Decree n. 193/1909 included mandatory technical (and hygiene) standards for repairs, reconstructions and new constructions of public and private buildings in municipalities affected by the aforementioned earthquake or other preceding seismic events. It also included criteria for choosing the building sites, the maximum height and the number of floors of the buildings, some urban planning requirements, and indications on the suitability of the construction systems. Moreover, the level of seismic resistance to be provided to the structure in order to avoid collapse on the occurrence of strong ground motions was set, but damage of structural members caused by such extreme events was allowed. The 1923 Great Kanto earthquake in Japan inspired the Japanese Urban Building Law, which used 10% of the weight of a building as horizontal forces for its design (linear static analysis) [4]. In 1927, the first seismic code (UBS) also appeared in the United States.

Nowadays, regulations concerning seismic stability have advanced from the original linear static analysis to dynamic analysis incorporating inelastic behavior. One of the most innovative solutions that was developed in 1970s in New Zealand, now used by most of the modern codes, is the capacity design approach, whereby structures are designed based on their ductility capacity, both at local and global level. This type of analysis takes into consideration the fact that failure may occur from the weakest link in the structure, and thus designs members in order to avoid any brittle failures and display ductility that will further extrapolate to the structure's global behavior.

At present, most of the European Countries have adopted EN 1998 Design of structures for earthquake resistance (EC8 [5]), which consists of 6 parts, of which Part 3, prepared in 2003 and adopted fully in 2005, applies to existing structures. Some of the clauses of EN 1998 – Part 3 are also adopted by the Italian New Seismic Code (2003). The desired Performance Level of the structure in different future seismic scenarios is decided mutually by the engineer and the owner of the structure. The number of Limit States to be considered, as well as the return period of seismic actions under which the Limit States should not be exceeded, are defined by EC8: Part 3 as Nationally Determined Parameters.

EC8 primarily describes the methodology that should be adopted for the verification of the response of a structure under specific ground motion. Both the correct simulation of the geometry and of the materials, as well as the correct characterization of the possible seismic ground motion are important for the outcome of the assessment. The failure mechanisms are estimated based on the forces and inelastic deformations, at global level, inter-storey level and component level.

Nevertheless, as stated in clause 1.1 (5) of EC8 - Part 3 [6], *“Although the provisions of this Standard are applicable to all categories of buildings, the seismic assessment and retrofitting of monuments and historical buildings often requires different types of provisions and approaches, depending on the nature of the monument”*.

EC8 - Part 3, in fact, includes a number of clauses regarding interventions for the seismic upgrading of an existing structure. It describes the technical criteria (5.1.1), the types of intervention (5.1.2), the fate of non-structural elements (5.1.3), the necessity of justification of the selected intervention type (5.1.4) and the results needed for the re-design of the structural intervention procedure (6.1).

Nevertheless, EC8 has not been fully adopted (or national annexes have not been issued) by many European countries (e.g. Denmark, Germany, Hungary, Ireland, Latvia, Poland, Slovakia, Sweden, UK [7]). It is worth stating that, where no national annexes exist, this is likely because the area is not prone to earthquakes. In contrast, in Greece and Italy, EC8 – Part 3 is at full use, with respective annexes, while additional codes for interventions also exist.

A.3 Vulnerability of historic concrete structures

Earthquakes that have occurred worldwide have explicitly shown the disadvantages and fallacies of previous design practices, that are usually the main causes of failure in old substandard structures: poor detailing with low strength and ductility materials (even without proper shear/confinement), discontinuous load paths, lack of proper lap splicing, weak column-beam joints, soft stories. One of the most important parameters that might have affected proper structural design in the past was the adoption of elastic methods of analysis, that did not take into consideration the formation of plastic hinges mechanism, or the brittle failures that could occur and the consequent redistribution of forces in other members of the structure.

As per EC8 - Part 3, the identification and elimination of major structural defects is a very important part of the entire retrofitting procedure. All local errors are to be appropriately remedied (5.1.2(2)a), and local ductility must be increased (if needed). Yet, older buildings (especially historic structures) may include materials or systems that may not be removed or altered. For the overall global performance of a structure, irregularities of stiffness and overstrength, both in elevation and in plan, must be rectified as much as possible by strengthening or the addition of new components, while the overall increase in strength after an intervention should not reduce the available global ductility. It is crucial that the retrofit procedure is compatible with the materials of the existing system and works in harmony with it, not creating any further damages and weaknesses.

The different deficiencies of historic concrete buildings may be grouped together in various categories [8]:

- (a) **Global strength** deficiency due to the absence of seismic design, or the design according to earlier codes with lower design values
- (b) **Global stiffness**; can be critical at different levels, usually at the lower ones when pilotis are designed at the ground floor, or short columns are created due to partial (in height) masonry infills
- (c) **Irregularities in plan and elevation** that place extensive deformations on specific elements due to the torsional response of the diaphragm (or are created by the uneven distribution of mass and stiffness between floors)

- (d) **Inadequate load Path continuity**, especially in cases where diaphragm collectors are not properly designed, columns are supported on beams, there is inadequate joint detailing, or inadequate construction joints
- (e) **Component detailing**, such as poor confinement due to the inadequate configuration and spacing of ties, brittle beam-column connections, short lap splices
- (f) **Diaphragms** with inadequate shear or bending strength, stiffness, inadequate reinforcing around openings or re-entrant corners, missing or inadequate collectors
- (g) **Foundations** due to lower bending and shear strength, inadequate axial capacity or detailing, weak connections, settlement, rotation
- (h) **Other deficiencies**, such as specific geological hazards (like liquefaction and landslides), pounding to adjacent buildings, deterioration or corrosion of structural materials

A.4 Restoration of historic reinforced concrete structures

The restoration of historic reinforced concrete structures may be carried out in a two-fold way. The first option is to enhance the capacity of reinforced concrete members by mitigating any brittle failures, and the second is to enhance the overall structural system capacity, by increasing the strength and ductility. The structural members may require increased shear strength, compressive strength, flexural deformation capacity and improved bond between the rebars and concrete, especially in places of lap splicing. This may be achieved by reinforced concrete jacketing, steel jacketing, and the application of fiber reinforced polymers (FRPs) for the confinement of structural members. For the enhancement of the system's strength and stiffness, addition of reinforced concrete shear walls, external frames, reduction of mass, retrofit of masonry infill walls and improvement of the inherent weaknesses of the structure, such as short columns or soft stories, may be applied.

Types of interventions prescribed by EC8 – Part 3:

- (a) Local or overall modification of damaged or undamaged elements (repair, strengthening or full replacement), considering the stiffness, strength and/or ductility of these elements;
- (b) Addition of new structural elements (e.g. bracings or infill walls; steel, timber or reinforced concrete belts in masonry construction; etc);
- (c) Modification of the structural system (elimination of some structural joints; widening of joints; elimination of vulnerable elements; modification into more regular and/or more ductile arrangements);
- (d) Addition of a new structural system to sustain some or all of the entire seismic action;
- (e) Possible transformation of existing non-structural elements into structural elements;
- (f) Introduction of passive protection devices through either dissipative bracing or base isolation;
- (g) Mass reduction;
- (h) Restriction or change of use of the building;
- (i) Partial demolition;

Any of the aforementioned interventions may be adopted alone or in combination; in any case, special attention must be given to the strengthening of the support system at the foundation level. Whilst when dealing with ordinary structures, the measures to be adopted may lead to extensive intervention requirements, with increased cost, that may eventually lead to the decision of no intervention at all, or indeed demolition of the structure, for the case of historic listed buildings, extensive transformation of the load-bearing system or demolition is not an option. In this case, the priorities of selecting the retrofit strategy change and, while in normal circumstances the important criteria would be (with descending

significance) cost, available workmanship and materials, duration and disruption, functionality, aesthetics, reversibility [9], for historical structures this list of priorities may be reversed.

The different interventions that may be proposed affect the overall behavior of the structural system in different ways; some methods increase the strength and stiffness, whilst others increase the ductility of the structure. The final decision is made on the basis of the assessment procedure, and more specifically on the relation between the Force-Displacement curve of the structure and the Performance Point (d_{et}), i.e. the level of deformation imposed by the design seismic action (see Figure 4).

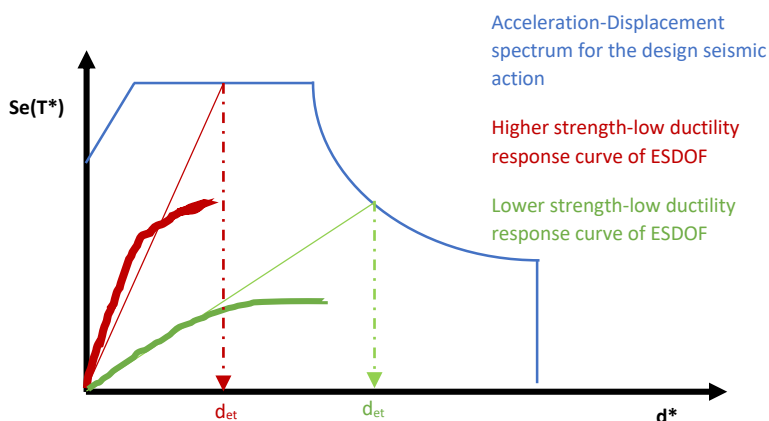


Fig. 4: Determination of the Performance Point, based on EC8.

In some cases, such an extensive upgrading is required, that the only solution is to lower the actual demand that will be imposed by the expected seismic excitation. This can be achieved by either minimizing the masses at the stories (i.e. changing the use of the building), removing the higher floors (not acceptable in the case of historic structures), or providing seismic base isolation (not always feasible or easy to apply).

Ductility enhancement without any other strengthening may be feasible in structures that have poor detailing, such as sparse stirrups -or no stirrups at all -, and consequently low confinement, unreinforced joints at the beam-column connections, short lap-splices. This procedure is sometimes enough to increase the overall ductility of the structure and transfer the capacity displacement to the right of the Performance Point (see Figure 4). In these cases, the structure's state after the design seismic action will be that of extensive cracking, albeit without collapse. In this regard, it is important that the owner of the structure realizes the high repair cost that will be required after a possible seismic event, in order to bring the structure back to its original state.

Stiffness and strength enhancement are effective in the sense that, by increasing the stiffness of the structure, a decrease in the fundamental period, and consequently in the displacement that will be required by the spectrum, is achieved. This type of intervention is possible only by the increase of the size of existing members, or the addition of new ones, that will be properly connected to the existing load-bearing elements and will resist horizontal displacements with their stiffness. In this case, the analysis should go further on the foundation system, since all these additional forces that will be enacted must be properly transferred to the ground.

EC8 - Part 3 also explicitly states that all non-structural elements must be repaired, strengthened and appropriately connected to structural elements, since their collapse (partial or full) may endanger the overall structural stability, the life of inhabitants, or the value of stored goods. The consequences of such

anchorage to the structural elements must therefore also be considered when assessing the performance of an existing structure under seismic loading.

The final decision on retrofit intervention must be extensively assessed and the expected results, in terms of strength, stability and ductility of the system, must be verified by a full structural assessment of the new system. Selected strengthening methods are listed below. EC8 - Annex A provides a series of procedures for determining the capacity models of these methods, in terms of flexure, shear, confinement, ductility, lap splices.

- Concrete jacketing (clause A.4.2)

The objective of wrapping reinforced concrete columns/beams/joints with reinforced concrete jacketing is to increase the axial load-bearing capacity, the flexural and/or shear strength, and the deformation capacity of the structural member, and to improve the strength of deficient lap-splices. If the jacket aims at increasing flexural capacity, the added longitudinal bars must continue to the adjacent stories. If only shear and lap-splicing is to be enhanced, then the jacket must have a gap of 10 mm with the adjacent slab. Special attention must be given to the transfer of the increased loads to the foundations.

Due to the requirement that the jacket should include both the longitudinal and transverse reinforcement (plus adequate cover), the required jacket thickness may be up to 10 cm; therefore, special attention is required when using this method in historic concrete structures, and more specifically in the cases of the so called “modern movement architecture”, where the slenderness of the members is part of the historic form.

- Steel jacketing (clause A.4.3)

Steel jackets can increase shear strength and improve lap-splices and ductility through confinement in columns. Plates or discrete horizontal steel straps are connected to continuous corner angles along the entire height. The jacket is activated when deformations begin to occur, while it works only as long as the jacket materials remain in the elastic range of their behavior.

This method also does not seem to agree with the provisions of listed buildings, as it fully covers the form of columns and changes the character of heritage structures.

- FRP plating and wrapping (clause A.4.4)

Externally bonded Fiber Reinforced Polymers (FRPs) are usually applied with the fibers in the hoop direction to increase the shear capacity of the strengthened members, enhance the available ductility and lap splice strength through confinement. The increase in flexural resistance induced is limited and usually neglected, while in no case FRPs may be used as flexural reinforcement, due to the reversed cyclic loading of seismic actions and their incapacity to sustain compression. FRPs are applied either as strips at the required distance, or sheets along the full length of a structural member. They may also be applied by fully wrapping a member around its cross section (four sides if rectangular column or three sides in beams). In any case, the contribution of FRPs does not extend beyond shear capacity under diagonal compression. For all cases where FRPs are used in rectangular members, the corners have to be rounded at a specific radius, to protect the FRP from rupture.

The FRP wraps, due to their small thickness, may be easily covered with plaster, without altering significantly the thickness of the strengthened structural members; thus, if used in historic structures, they are not visible. They are also a reversible type of intervention, as they can easily be removed. Special attention must be given to the case where the structural members are fully covered and the materials cannot breathe.

Other strengthening methods not described in detail by EC8 - Part 3 are also listed below:

i. Addition of reinforced concrete walls

Although the addition of reinforced concrete (RC) walls is an option provided by EC8, the exact procedure of determining the dimensions of these walls, detailing and proper placement is not defined. The addition of reinforced concrete walls must cover the entire height of the structure, connecting properly with the slabs and foundations, and should not create asymmetries of stiffness in plan.

Such an intervention in historic structures must be properly placed in places that could be hidden and would not alter the original form of the structure.

ii. Steel bracing

Steel bracing systems that are placed within existing frames can increase the strength and stiffness of a structure. They are preferred architecturally over RC walls, as they are easily retractable and the frames they are used in are not completely covered. If special attention is given to color and dimensioning, steel bracing may fit with the surrounding frames and be discrete, while it also light (thus not increasing the mass of the structure) and easy to handle. Special attention must be given to connection to existing frames.

Retrofitting strategies that lower or diminish the seismic demand include:

- a. Energy dissipative devices
- b. Damping systems
- c. Seismic Isolation
- d. Reduction in mass

Other methods:

- External frames
- Retrofit of masonry infill walls
- FRP strengthening of masonry infill walls
- Use of novel strengthening materials: UHSC, FRC, TRM

A.5 Implementation of seismic codes in the 4 countries participating in CONSECH20 and practices used for the seismic retrofitting of historic structures

This section provides a review of the standards and procedures used in the 4 partner countries regarding the seismic rehabilitation of historic concrete structures.

A.5.1 The Netherlands

The Netherlands is not located in a high seismic zone. Traditionally, there has not been a mandatory building code or norm addressing the seismic requirements for new or existing buildings [10]. However, since 1986, the northern part of the country has experienced over a thousand seismic events, likely attributed to the extraction of shale gas, which started in the 1950s. The most affected part of the Netherlands has been and still is the province of Groningen (last relevant seismic event was reported in 2019).

The aforementioned seismic events, due to their origin, mostly affect the upper strata of the ground, resulting in a lower intensity than natural occurring earthquakes, although in 2012 one specific event reached a magnitude of 3.6 in the Richter scale. Gas extractions seem to have been reduced, but are nevertheless planned to continue until 2030.

A Dutch project [11] was introduced in 2015 to mitigate the risk of damage due to induced seismic events in unreinforced masonry and precast concrete buildings. Towards that direction, a provisional Dutch Practical Guideline NPR 9998+C1 [12] has been developed for the design and assessment of the resistance against earthquakes of (i) new to be built, (ii) to be reconstructed (reinforced) and (iii) existing buildings.

In summary, NPR 9998+C1:

- provides guidance to assess whether:
 - a. new to be built buildings are sufficiently earthquake-resistant,
 - b. existing buildings are sufficiently earthquake-resistant,
 - c. existing buildings are sufficiently earthquake-resistant after being reinforced.
- is based on NEN 8700 [13] and NEN 8701 [14];
- introduces the first steps towards the development of National Annexes in line with the specifications of EC8 (NEN EN 1998) [5];
- is meant to be applicable only in the Groningen Province (north part of the Netherlands).

By definition, the recommendations of NPR 9998+C1 [12] apply to existing buildings (including concrete buildings); thus, historic concrete monument buildings are included under this definition. However, the norm specifies a set of seismic requirement parameters for which monuments can be exempt. The most important of these parameters are the impact of human safety, the structural safety of the building after an earthquake, and the decision of the owners and local authorities upon the monument.

As such, the recommendation of NPR [12] is not straight forward whether monuments in the region of Groningen must be seismically retrofitted or not. NPR not only takes into consideration the monumental status of the building, but also other aspects, such as

- the reversibility of the intervention, once the time of the induced-earthquakes has passed;
- the conservative approach of this type of assessment, which may lead to unnecessary interventions;
- the probabilistic cause that human safety is in danger (if there is no danger, then seismic retrofitting is not considered necessary); and
- the voice of local authorities and monument owners.

In addition, the norm sets different safety levels for existing buildings: SD (significant damage), DL (damage limitation) and NC (near collapse). The owner of the building may choose the required safety level.

In section 1.1, the norm states:

In principle, when choosing a solution for preserving monuments, any possibility between the following two extremes can be chosen:

- a) An intervention where the monument is reversibly reinforced, such that the requirement of the individual risk of 10^{-5} is fulfilled, and furthermore no form of damage whatsoever due to an induced earthquake is accepted. When the period in which ground motions due to earthquakes has ended, the reinforcement options will be undone to restore the original look of the monument.*
- b) Not implementing any reinforcement interventions whatsoever, thus temporarily accepting an increased individual risk, as well as possible damage during the period in which seismic ground motions can occur. The damage is repaired after this period.*

In order to aid the authorities' decision-making regarding monuments, Annex K contains supporting information that can be consulted. Nonlinear analysis methods that have been validated against sufficiently relevant test results should preferably be used. More complex analysis methods may possibly lead to more accurate results, but the simpler analysis methods can be more appropriate in order to visualize the resistance to seismic actions using susceptibility analyses.

Annex K acknowledges the fact that many monuments should be reinforced [to withstand seismic actions]. The basis of NPR recommendations is human safety and this is based on the requirement that the individual risk (IR) of dying due to the effect of an earthquake shall not exceed 10^{-5} in a year. This means that the focus of this recommendation is on structural safety. Nonetheless, the local authorities can justify, with “good motive”, that the monument does not need to comply with the $IR \leq 10^{-5}$ criterion.

Another aspect considered in Annex K is the probability of people dying in a non-seismic resistant monument building. For instance, if the monument is used as offices, the chances are greater than for a church that is open for a few hours every week. If people live in a monument, or spend much time there for other reasons, this can be an urgent reason to assess and reinforce the building.

A.5.2 Czech Republic

EC8 [5] is normative in the Czech Republic, and there is a National Annex (ČSN EN 1998-3 [15]) that describes the criteria for the evaluation of existing building structures in terms of earthquakes, as well as procedures for selecting measures for structural repairs and reinforcement design. This also includes the dimensioning of load-bearing parts and their connection to existing load-bearing elements.

ISO 13822 [16] - Principles of Structural Design and Evaluation of Existing Structures is also implemented in the Czech Republic as ČSN ISO 13822. It has 5 annexes with specifications on materials.

Instructions for the use of ČSN ISO 13822 [16] are given in ČSN ISO 13822 (730038) [17], which applies to the design and assessment of load-bearing structures with alterations and repair interventions made of reinforced concrete, masonry, wood, or a combination of these materials.

Fundamental principles for the assessment of buildings (and bridges) with a cultural heritage value are provided in Annex I of ISO 13822 [16]. ČSN ISO 13822 (730038) [17] (and the relevant ČSN ISO 13822, which is based on ISO 2394), applies as well and contains a part dedicated to the assessment of cultural monuments. The assessment described in ISO 13822 [16] is linked to the heritage value and structural reliability of a structure. Heritage value is based on different aspects: historic materials, special configurations, structural design, cultural associations, construction works, technologies and non-structural cultural features, such as murals. The heritage value(s) of a building, its structure and

associated technologies are defined by preservationists and architects. These values should be considered in any plans for the future use of the building and the design of construction interventions.

The heritage value of a historic structure resides in the authenticity and integrity of its character-defining elements. To retain authenticity and integrity, the structure shall be preserved, as far as possible, with its original materials and structural concept. An over-cautious approach to structural assessment should be avoided, because it can lead to unnecessary structural interventions, and result in loss or major alteration of heritage character-defining elements and, ultimately, in the loss of authenticity and historic significance of the cultural resource. The performance level must take into consideration both the safety of the users and the protection of the cultural resources. Scenarios for potential interventions shall respect heritage values. The heritage values normally place severe restrictions on possible interventions and, therefore, more than one scenario should be assessed. The following guidelines are to be followed:

- (a) Minimal interventions that least harm the heritage values
- (b) Compatible materials in terms of mechanical, chemical and other characteristics, that do not induce harmful effects, such as corrosion or decay
- (c) Avoid removal or alteration of historic materials and features
- (d) Where possible, measures adopted should be removable

A.5.3 Italy

The new Italian Building Code (*Technical Standards for Construction - Norme Tecniche per le Costruzioni, NTC2018* [18]) is fully consistent with EC8 - Part 3 (EN 1998-3 [6]). NTC2018 [18] specifies, for each category of intervention, the condition of application, sanctioning the obligation of static testing (*collaudo*), not only for adaptation/retrofitting interventions, but also for structural improvement interventions. Some fundamental intervention criteria are then defined, common to all types of interventions, such as the search for regularity, the attention needed for the execution phases and the priorities to be assigned, whilst the most usual interventions for the various structural types are examined. In order to correctly evaluate the possible use of buildings, the technician in charge of the project, i.e. the civil engineer, must specify in the structural design reports the current safety levels and those that any intervention aims to achieve, as well as any consequent limitations in the use of the construction. The engineer must then also explain, as far as possible, the level of safety of the non-structural elements. The set of current regulations, in fact, also allows the use of existing buildings that do not reach the safety levels¹ required for new buildings.

Following the general criteria on the different types of buildings and the variables that allow to define their state of conservation, Section 8 introduces the fundamental distinction of the three different types of intervention that can be carried out on an existing building:

1. repairs or local interventions, which involve isolated elements, and which in any case lead to an improvement of the pre-existing safety conditions.

¹ In fact, the norm reports that "with respect to seismic action checks, the safety level of the building is quantified through the ratio ζ_E between the maximum seismic action bearable by the structure and the maximum seismic action that would be used in a new building project; the entity of the other actions present at the same time is the same as that assumed for new buildings, except for what emerged on the permanent vertical loads following the investigations conducted (referred to in § 8.5.5) and except for the possible adoption of specific restrictive measures on the use and, consequently, on variable vertical loads. The restriction on use can change from portion to portion of the building and, for the i-th portion, it is quantified through the ratio $\zeta_{v,i}$ between the maximum value of the vertical variable overload bearable by that part of the building and the value of the variable vertical overload that would be used in the design of a new building."

2. improvement measures, aiming at increasing the existing structural safety, even without necessarily reaching the levels required by NTC2018 [18];
3. adjustment interventions aiming at achieving the safety levels envisaged by NTC2018 [18].

In general, safety assessment consists in identifying the critical issues with respect to the considered actions, both non-seismic (such as own weights, overloads and climatic actions) and seismic. If the seismic response of a structure does not fulfil the standard required by the code, the gap should be filled by seismic upgrading interventions. Increasing the safety level of the building against collapse is the primary goal of retrofit interventions. However, a reduced damage of structural and non-structural elements in the occurrence of moderate earthquakes, and a limited disturbance to the occupants of the building during the realization of the retrofit interventions, should be considered as further important goals in the choice and application of the retrofit technique. Many strategies may be embraced to pursue these objectives. The most classical way is to increase the strength and/or ductility capacity of the structure at global or local level.

For interventions aiming at reducing the seismic vulnerability of listed cultural heritage assets, the regulatory framework in Italy, pending the issuance of further provisions, is D.P.C.M. February 9, 2011 "*Evaluation and reduction of the seismic risk of cultural heritage with reference to the technical standards for construction referred to in the ministerial Decree of January 14, 2008*". This directive, in light of the specificity and articulation of the content, and of the characteristics of the Italian historical built heritage, as well, can be used as a reference for existing constructions that in any case have a historical, artistic or urban-environmental value, even if not explicitly listed and protected, except as provided in point 8.4 "Classification of interventions" of NTC2018 [18].

Any restoration interventions on listed buildings are entrusted to an architect, which can also operate with regards to all restoration interventions to be carried out on buildings having significant artistic character, albeit not listed. In fact, according to the current legislation, the competence in architectural restoration interventions is solely attributed to the abovementioned professional figure, who has the professional exclusivity, by virtue of the type of educational background and qualification acquired. In the Italian Cultural Heritage and Landscape Code, the term '*restoration*' is intended to mirror all the operations attributable to this category of intervention, as defined by article 29, comma 4: '*By restoration it is meant the direct intervention on the asset through a complex of operations aiming at the material integrity and recovery of the asset itself, and at the protection and transmission of its cultural values. In the case of properties located in areas declared to be at seismic risk, according to the current legislation, restoration includes the intervention of structural retrofitting*'.

Despite many research projects and dissemination and communication initiatives² at national, regional and local level, too little has been done in Italy to-date concerning the improvement of effective guidelines for the conservation of 20th century historic concrete buildings. There is no unitary disciplinary corpus with a shared defined structure, built around methods, tools and practices, on which different actors acting in the field of conservation of cultural heritage can rely on. On the other hand, there is a lot of knowledge produced in the last 40 years, since the beginning of the debate on modern architectural heritage. Moreover, recent and on-going initiatives, such as the *Censimento nazionale delle architetture italiane del secondo Novecento* promoted by MiBACT, tried to establish some basic criteria that only partially can be considered quantitative (e.g. bibliographical recurrence) and

² Among these initiatives, it is worth mentioning the *Censimento nazionale delle architetture italiane del secondo Novecento* (National census of the Italian architecture of the second half of 20th century) carried out by MiBACT central and local bodies, in cooperation with Italian High Educational Institutions. See: <http://architetturecontemporanee.beniculturali.it/> (Accessed, 10 November 2020)

qualitative-critical (technological novelty, typological scheme renewal, technical or social problems solutions, etc.).

Unfortunately, both the amount of knowledge produced until now and the above-mentioned basic qualitative, quantitative and critical criteria, despite constituting a ground background, still are not comprehensively reflected into the national legislation framework. At the same time, to critically guide the conservation actors through the restoration and reuse process, neither effective national guidelines nor established practical procedures based on the wide and different highly representative variety of 20th century concrete buildings, with their respective conservation practical and theoretical problems and relative solutions, are available.

A.5.4 Republic of Cyprus

In Cyprus, buildings constructed until 1994, when the first Cypriot Seismic Standard became mandatory, were designed without any seismic provision and detailing. The establishment of the first anti-seismic measures was initiated in 1979, following a destructive earthquake with various casualties that took place in Thessaloniki, Greece. The lack of local authorities (the island was under British administration until 1960) and/or universities and research centers (first university department in civil engineering locally established in 2003) are probably some of the factors that delayed so long the need for application of local regulations concerning the stability and safety of RC structures. The first local Seismic Zone Map was issued in 1986, while in 1992 the Cypriot Seismic Code was introduced, initially as an option, before it became mandatory in 1994. In 2012, the Eurocodes (incl. EC8 - Part 3 [6]) superseded all other national documents and are thus now solely used for the construction of new or the repair of existing structures on the island.

The national Annex to EC8 - Part 3, nevertheless, mentions in Clause 2.1 that, for buildings of Importance classes I-III, the number of limit states to be checked shall be agreed between the owner and the designer, as well as the return periods corresponding to the various limit states. With this option available, the possibility of assessment only for the worst-case scenario, i.e. collapse prevention for the frequent event with 20% probability of exceedance in 50 years, is possible. Furthermore, the Ministry of Interior issued a Guideline Document in 2012, giving the option of adding floors on existing structures without provisions for seismic loading, or requirements for the retrofit of the existing structure, if the owner so decided. Under pressure by the local engineering community, and with some legal issues raised by this practice, in November 2020, a new Guideline document was issued considering the addition of floors on existing structures; this document sets some minimum design accelerations for the assessment of the existing structure and the design of the addition. These minimum values are lower than the performance points set for new structures.

The Republic of Cyprus has adopted and/or signed all existing agreements for the protection of architectural heritage (e.g. Venice Charter (1964), Amsterdam Declaration (1975), Granada Convention (1985), International Charter for the Protection of Historic Cities (1987), etc.). The basic principles that should be followed for the repair and maintenance of “traditional” (this is the exact wording used by the Department of Town Planning and Housing, which is responsible for historic listed monuments in Cyprus, and it clearly shows that what has been done so far is oriented towards traditional masonry structures) structures are:

- (a) The maintenance of a building involves the maintenance of all its elements (original traditional materials, construction details, finishes, paintings/ decorative elements, etc.), as well as of its immediate environment and scale. Consequently, any alteration that could change its volume, shape, materials and colors shall be excluded.

- (b) New additions must respect all parts of the building, its traditional context, the balance of its composition, its relations with the surrounding area, and at the same time they must be separated from the original parts of it, bearing the seal of their time. In addition, new additions must be as reversible as possible, so that the building can be restored to the situation it was before the intervention (reversibility principle).
- (c) Mostly traditional materials and building methods should be used; only where these are deemed insufficient, modern techniques should be applied, for which the effectiveness and compatibility with traditional materials must be demonstrated scientifically and empirically.

For any interventions on a listed building (maintenance, building work or conversions), in addition to the required permits in accordance with the National Legislation (Urban Planning Permit, Building Permit), special permit (Internal Affairs Minister's Consent) must be secured. The Consent on Listed Buildings throughout Cyprus, except for those located within the boundaries of the Municipality of Nicosia, is issued by the Director of the Department of Town Planning and Housing. Regarding the listed buildings located within the boundaries of the Municipality of Nicosia, the Consent is issued by the Municipality itself.

Guidelines for the restoration of listed buildings, the materials, procedures and additions acceptable, are provided in an extended General Terms document published by the Department of Town Planning and Housing; however, nothing solid exists for the case of reinforced concrete structures. If one examines the RC listed buildings that have undergone repair/maintenance, there is not a sole unified policy concerning either the upgrading scope, or the materials, methods, techniques and strategies used. In terms of strength and ductility against seismic action, some of these buildings were only subjected to minor refurbishment, without any structural intervention, in order to be re-used, and some have undergone serious interventions, such as concrete jacketing, addition of shear walls or FRP wrapping. The strategy of intervention and re-use is decided case-by-case.

PART B: Fire Safety

B.1 General aspects of fire safety for historic structures

Fire is one of the main causes of loss of historic structures. There have been various examples in recent years concerning this matter: two very important historic concrete structures that were lost due to fire are the landmark Faculty of Architecture Building at Delft University of Technology and the Grenfell Tower 24-storey block of brutalist architecture in London, shown in Fig. 5. The consequences of the loss of such structures are not only related to the structures themselves, that encompass significant architectural/social/cultural significance, but also in many cases refer to the loss of the objects that are included in them, that are sometimes irreplaceable, such as book collections, archives etc.



Fig. 5: Faculty of Architecture Building at Delft University of Technology (top) and the Grenfell Tower 24-storey block of brutalist architecture in London (bottom)

The Eurocodes include specific provisions concerning fire design for the design of new and the retrofit of existing buildings:

- Eurocode 1 (EN 1991-1-2) “General actions – Actions on structures exposed to fires” [19]
- Eurocode 2 (EN 1992-1-2) “General rules – Structural fire design for Concrete” [20].

These provisions consider the safety of occupants in the case of fire and are related to the load-bearing capacity of the buildings for a specific period of time, the limitation of the spread of fire and smoke within the building, the limitation of the spread of fire to neighboring structures, the rescuing of the

occupants and the safety of the rescue teams. The Eurocodes prescribe the selection of thermal actions, the coefficients for load combinations, the reduction factor for the design load in a fire situation, the calculation models (advanced or simple), the material properties etc. Of course, these design methods are most suitable for new structures. Additionally, there are some regulations and local codes of practice concerning fire, but these are again not specific for the case of heritage structures:

- EU – EN 54-1 Fire detection and fire alarm systems. Introduction.
- EU – EN 54-1 Fire detection and fire alarm systems. Planning, design, installation, commissioning, use and maintenance.
- DE - DIN VDE 0833-1 Alarm systems for fire, intrusion and hold-up. Part 1: General requirements
- DE - DIN VDE 0833-2 Alarm systems for fire, intrusion and hold-up. Part 2: Requirements for fire alarm systems
- UK - BS 5839-1: 2013 Code of practice for design, installation, commissioning and maintenance of systems in non-domestic premises
- UK - BS 9999:2008 Code of practice for fire safety in the design, management and use of buildings
- UK - Approved Document B (Fire Safety) Volume 2 (Buildings other than dwelling houses)

For the case of historic structures, no specific codes exist and there are limitations in the available options, due to the significance of maintaining and preserving original materials, fabric and architectural features. Some important studies concerning the fire protection of historic structures have recently been carried out [21], while COST Action C17: Built Heritage: Fire Loss to Historic Buildings has also produced practice guidelines that have been adopted by the European Fire Protection Association (CFPA E) as Guideline No 30:2013 F - Managing fire safety in historical buildings [22].

One very important aspect concerning fire safety is the change of use of historic structures and the installation of new equipment after they become public places, museums or galleries, with different number of users being served. It is important to note that, as per the seismic design provisions, in fire protection a case-by-case scheme should also be elaborated; this should take into consideration both the specificities of the structure itself and the new type of use.

The first step that should be taken is the preparation of a Risk Assessment study that should be linked to a specific level of fire safety that highlights potential problems; this may be used as a guide to determine possible fire protection measures. All the information should then be gathered in a Fire Safety Handbook that includes floor plans with locations of fire extinguishers, hose reels, hydrant points, gas shut-off valves etc.

B.2 Fire protection measures for historic structures

Fire protection measures for historic structures may be grouped in four different categories that include passive and active measures for: (a) the prevention of fire ignitions, (b) the prevention of fire spread, (c) evacuation and (d) salvage of items of historic value.

- (a) Prevention of fire ignition can be related to problems of arson, electrical installation and equipment, open fires, smoking materials, candles, heating equipment and hot works. Some of the measures that should be undertaken for these causes are very simple, such as the proper cleaning of waste from around the premises, keeping doors and windows closed, maintenance of electrical equipment, monitoring systems that turn electrical appliances off when forgotten, main equipment placed in a suitable environment and not exposed to e.g. humidity, electrical installations not overloaded, chimneys and fire places cleaned regularly and hot works during maintenance or renovation performed under strict control.

- (b) Prevention of fire spread is related to the removal of one of the three elements needed to ignite and spread a fire: oxygen, fuel, heat. The basic equipment for this is fire extinguishers -especially selected for the expected type of fire without harming or damaging the building -, blankets or other systems. Another measure that is usually taken in new constructions is fire compartmentation, by special door assemblies, for example; this prevents fire spreading, but sometimes it is difficult to adopt in historic structures. Additionally, installation of detection and extinguishing systems, such as sprinklers and water mist, is another available option, but these systems must be minimally invasive, sensitively integrated and reversible. New solutions such as Hypoxic Air Venting are also an option for historic structures.
- (c) Evacuation in the case of a fire is of crucial importance for the protection of human life. For this purpose, an escape alarm and other protection measures must be installed, since escape routes are not always possible solutions for historic buildings. Usually, if the capacities are not the ones required, then a restriction of access to visitors is usually applied, thus limiting the number of users. In modern codes, there are also maximum distances to the final exits (i.e. 15 m), which in historic structures may be longer. Additional external staircases may also be used, since in many cases buildings have been constructed with only one exit. Furthermore, specific considerations must be fulfilled for doors on escape routes, while guidance signs must be installed in suitable positions with a plan of escaping routes.
- (d) In cases where important items of historic value exist in a building, special consideration must be given to their location or the use of special equipment, and also a plan of evacuation and damage limitation must be made to prevent crowding of routes and congestion of personnel.

B.3 Implementation of fire safety in in the 4 countries participating in CONSECH20 and practices used in historic concrete structures

B.3.1 The Netherlands

The Dutch Building Regulations ([Bouwvoorschriften](#)) [23] include different codes (housing, environmental, fire safety, buildings, energy, etc.) that provide the minimum requirements existing and new buildings should meet. The fire resistance of existing concrete structures can be determined according to the same procedure and standards as for new buildings. No specific standards have been developed to assess the fire resistance of existing structures, and the engineer is recommended to consult NEN-EN 1992-1-2:2011 (Eurocode 2) [24] and NEN 6069:2011 [25].

A specific material characteristic fire resistance or the reaction to fire propagation classification can be prescribed in the regulations for a certain aim. The determination method (test method) of that characteristic is included in the EN standards. The results of the tests (e.g. the fire rating of the material) are included in a certificate. Hence, if a certificate is present, it can be easily determined if a material meets the prescribed requirements. Without a certificate, it must be proven in a different way whether a material meets the prescribed requirements. In terms of how to determine whether the elements in an existing building comply with fire safety requirements, the reference Dutch standard is NEN 6069: Testing and classification of the fire resistance of building parts and construction products [25]. In this standard, reference is made to EN 13501-1 [26], which describes the test method to determine the fire rating of materials and building elements.

The only exception for fire safety in the Dutch Building Regulations are monuments. According to Section 1.3 of the Dutch Building Decree 2012 [27], regarding monuments, *“If the environmental permit deviates from the regulations of this Decree, the regulations of the environmental permit apply and exclude the*

relevant regulations in this Decree". Therefore, monumental buildings do not require to comply with the Building Regulations. However, Section 10.3 states that, if a monument does not meet the minimum requirements for a specific use, then the use of the building for that purpose is not allowed. In practice, this only means a limited use of the monument. In fact, the number of people/users allowed is related to the capacity of the escape routes, and if this is limited in a monument, the number of people/users will also be limited.

Furthermore, with regards to the analysis and characterization of the materials, often it is not possible to find out which products have been used in existing buildings (including monuments). Also, in some occasions, those products cannot be tested according to the current test methods. In these cases, an expert person will assess the material property of a product. This assessment is called an Expert Judgment. This can be used to determine whether an existing building meets the required minimum standards for its intended.

B.3.2 Czech Republic

In the Czech Republic, the Fire Protection Act No. 133/1985 Coll outlines the general principles of the fire protection system, the responsibilities and the structure of the organisation of the fire brigades. Measures for fire prevention are specified in several Decrees:

- Decree No. 246/2001 regarding Fire Prevention (modified in Decree No. 221/2014);
- Decree 23/2008 regarding Technical Conditions for Fire Protection of Buildings (modified in Decree No. 268/2011);
- Decree No. 268/2009 Coll. regarding General Technical Requirements for Buildings.

The aforementioned Decrees refer to Technical Standards, both Czech and European. Some of the Czech Technical Standards were unified with the Standards of the European Union during the last decades. This unification was required in particular for the so-called "Material" and "Product Standards", on the basis of free trade competition, whereas "Project" or "Design Standards" remain in the national version.

The general frame of the construction agenda (e.g. the licencing processes) is outlined by the Construction and Urban Planning Act No. 183/2006 Coll., where the involvement of the fire protection organs is also prescribed.

The fire safety assessment encompasses the *Required Fire Resistance of the Structure*, which is expressed by the period of time this can resist a fire (e.g. 60/90/120 min, depending on type of the building, its height, function and other aspects). In the case of smaller construction elements, fire resistance can be measured experimentally by "fire testing" of a prototype. In other cases, the fire resistance of the structure can be calculated using the Eurocodes (ČSN EN 1991-1-2) and the method described in the Czech Technical Standards (ČSN 73 0821, ČSN 73 0834). Both methods of calculation are suitable for existing structures and have been considered safe according to Hejtmánek, et al.[28].

The Fire Safety Act defines the structure of the Fire Protection Organs, including those responsible for fire prevention. The Construction and Urban Planning Act defines the cases where this binding protocol of the Executive Organs of Fire Safety is necessary. In case of doubts, it is the officer of the local Construction Agenda Department who issues the final decision. In case the binding protocol of the Fire Safety Authorities is required, an expert, i.e. a licenced fire protection technician³, prepares a Fire Safety Project and submits it (together with other parts of the project documentation) to the fire protection executive organ (commonly the Department of Fire Prevention of the Regional Fire Brigade). The executive organ assesses the project and issues the binding protocol (as acceptable, unacceptable or

³ The licences for fire security experts are issued by the Czech Chamber of Authorized Engineers and Technicians Active in Construction (ČKAIT), according to Act 360/1996 Coll. about Authorization of Architects, Engineers and Technicians.

acceptable with particular conditions). An acceptable protocol is a necessary part of the documentation to be submitted to the local Construction Agenda Department, when applying for construction licence.

In the case of restoration/conversion of an existing building, the fire assessment relies in verifying whether the building meets the safety requirements or can be properly adapted⁴. The architect and the client often face a dilemma: to preserve the original state and accept the use restrictions, or apply the necessary measures for a new use. Regarding protected buildings, the possibilities of application of the fire security demands are even more limited. In many cases the main problem is not the structure itself, but the typology. Different demands on the dimensions of evacuation corridors and stairs led to restrictions of use in several public spaces.

There are also many modernist buildings facing the need of adaptation to the recent legislation; their problems are very specific, and not easier to resolve than those of the older structures (e.g. glass facades or several floors connected into an open plan complicate the required division into separated fire sections, building with steel load-bearing structure etc.).

There are a few points in the Czech legislation focusing on Cultural Heritage. Paragraph No. 26 of the Implementing Decree 23/2008 Coll. expresses special demands for heritage buildings:

- a) a fire alarm system or a smoke detector integrated into a security alarm system must be installed in such buildings, and
- b) a permanent fire-extinguishing system (water sprinkler system) must be installed in unique spaces of the heritage buildings, or in the spaces containing unique heritage objects.

Besides the requirements defined by law, there are also several programmes run by the Heritage Protection Institutions, together with the Fire Security Authorities and other partners. A notable project of these institutions, entitled the Guidelines and the Database of the Fire Security of Heritage Buildings [29], was carried out in 2013-2015. It brought advancements in the theoretical field, as well as in practice: the assessment of the fire safety of several monuments administrated by the National Heritage Institute (e.g. National Castles), the definition of the minimal standards of the fire protection of the Cultural Monuments and the establishment of guidelines for the administrators of heritage buildings [30].

B.3.3 Italy

A uniform application of the fire prevention measures, DM 03/08/2015 "*Fire Prevention Code*", was drafted, considering the recognized international standards, adopting their terminology to ease bibliographic and technical research. In 2019, in order to simplify and rationalize the regulatory body relating to fire prevention, through the use of a new methodological approach more adherent to technological progress and international standards, the 2015 Fire Prevention Code has been modified by Ministerial Decree 12/04/2019 (Published on the Official Bulletin n. 95 of 23/04/2019). The changes made by the 2019 DM entered into force in October 2019.

Concerning fire risk prevention in listed buildings, the first regulation addressing fire safety issues was the Royal Decree n. 1564, November 7, 1942 "*Rules for the implementation, testing and operation of technical plants within buildings having artistic or historic values and in those intended to contain libraries, archives, museums, galleries, collection and objects of cultural interest*". More recent standards aiming at the fire protection of buildings of cultural interest were published in 1992 (DM 20/05/1992, n.569 "*Fire safety standards for historic and artistic buildings intended for museums, galleries, exhibitions and shows*") and in 1995 (DPM 30/6/1995 n. 418 "*Regulations containing fire safety rules for buildings of historical and artistic interest intended for libraries and archives*"). The rules included in the 1992 regulation govern the technical measures necessary for the release of the Fire Prevention Certificate by the command of local firefighters.

⁴ One of the Czech Technical Standards (ČSN 73 0834) is dedicated to the Adaptations/Redesign of existing buildings.

Art. 9 of DPM n.569/1992 provides for fire safety measures, reporting that within a listed building a portable fire extinguisher with capacity not less than 13 A, must be provided for every 150 m². Moreover, all fire extinguishers must be arranged uniformly along the path open to the public in a clearly visible, signposted and easy position. Concerning the fire-fighting water system, it must be structured as a closed ring net, equipped with UNI45 connections, that may be used for linking flexible hoses or hose reels. The water system must comply with a minimal capacity of 240 l per minute for every column having more than two fire extinguishers, ensuring the supply of minimum 120 l to the less accessible fire extinguishers with a 1.5 bar pressure at their nozzle, lasting at least 60 minutes. Moreover, a delivery connection for fire trucks must be installed near the main entrance in a signposted position and easily accessible by the emergency vehicles of the firefighters. The hydrants must be placed on each floor near the entrances, stairs, exits, risk rooms and deposits, while fixed fire-detection automatic systems must be installed and connected by means of a special control unit to optical and/or alarm devices. The alarm system must be such as to allow an orderly outflow of people from the building. Another important aspect contained in this DPM, are the emergency and safety plans that allow the handling of a possible emergency situation (art. 10 and art. 11).

The architectural and structural characteristics of listed buildings sometimes make it difficult to apply technical standard rules, which can be implemented in some cases only through invasive interventions, incompatible with the buildings' historical-artistic constraints. The Fire Prevention Code in force foresees the possibility to ask for derogation, allowing the architect, after careful risk assessment, to determine alternative safety measures to those provided in the technical rules. When the derogation procedure is activated, the design solutions that must guarantee fire safety conditions can be identified, by referring to safety engineering directives (Ministerial Decree of 9 May 2007 "*Directives for the implementation of the engineering approach to fire safety*") or to the solutions proposed in the 2016 Guideline (see below), aiming at ensuring uniform judgment in the evaluation of projects by the subjects in charge.

The more specific regulation in force, concerning listed buildings, is represented by Circular letter DCPREV prot. n. 3181, March 15, 2016 "*Guideline for the evaluation, by way of derogation, of building projects subject to protection pursuant to Legislative Decree 22/1/2004, n. 42, open to the public, intended to contain activities of Annex 1 to the Presidential Decree – DPR n. 151 August 1, 2011*" issued by the Ministry of Interior, Department of Fire Brigade, Public Aid and Civil Defence – Central Directorate for Prevention and technical Security.

In the presence of public activities, the cultural asset protection contributes to that of the safety of human life enshrined in art. 13 of Legislative Decree no. 139/2006. Therefore, the conditions of subjection depend on the intended use of the listed building. Annex 1 lists activities subject to fire prevention visits and checks. Activity n. 72 (att. n. 72) concerns public activities in "*Listed buildings subject to protection pursuant to Legislative Decree 22/1/2004, n. 42, open to the public, intended to contain libraries and archives, museums, galleries, exhibitions, as well as any other activity contained in this Annex*". Figure 6 shows the operational decisional process used to implement measures for fire risk prevention in listed buildings.

DPR n. 151/2011, Annex 1, att. n. 72 applies to:

- (a) libraries and archives, museums, galleries, exhibitions and exhibitions open to the public, located within listed buildings pursuant to Legislative Decree 22 January 2004, n. 42;
- (b) one or more activities listed in DPR n. 151/2011, Annex 1, and is therefore subject to the obligations therein, if those are open to the public and carried out within listed buildings pursuant to Legislative Decree no. 22 January 2004, n. 42.

However, if the listed building is only partially occupied by libraries and archives, museums, galleries, exhibitions, the activity referred to att. n. 72 is limited to the portion of the building in which the public activity is carried out. It should be noted that for galleries, museums, etc., having a surface area greater

than 400 m² and hosted within unlisted buildings, activity, att. n. 69 (att. n. 87 ex DM 16/02/82) applies and it is not necessary to apply specific rules according to DM 20/05/1992, n.569, since the buildings are not listed. Moreover, galleries, museums, etc. inside unlisted buildings and with a surface not exceeding 400 m² are not subject to fire prevention controls, as att. n. 72 applies to buildings subject to protection and not to the objects contained in them, unlike as it was foreseen in the previous att. n. 90 (current att. 72) of the DM 16/02/1982.

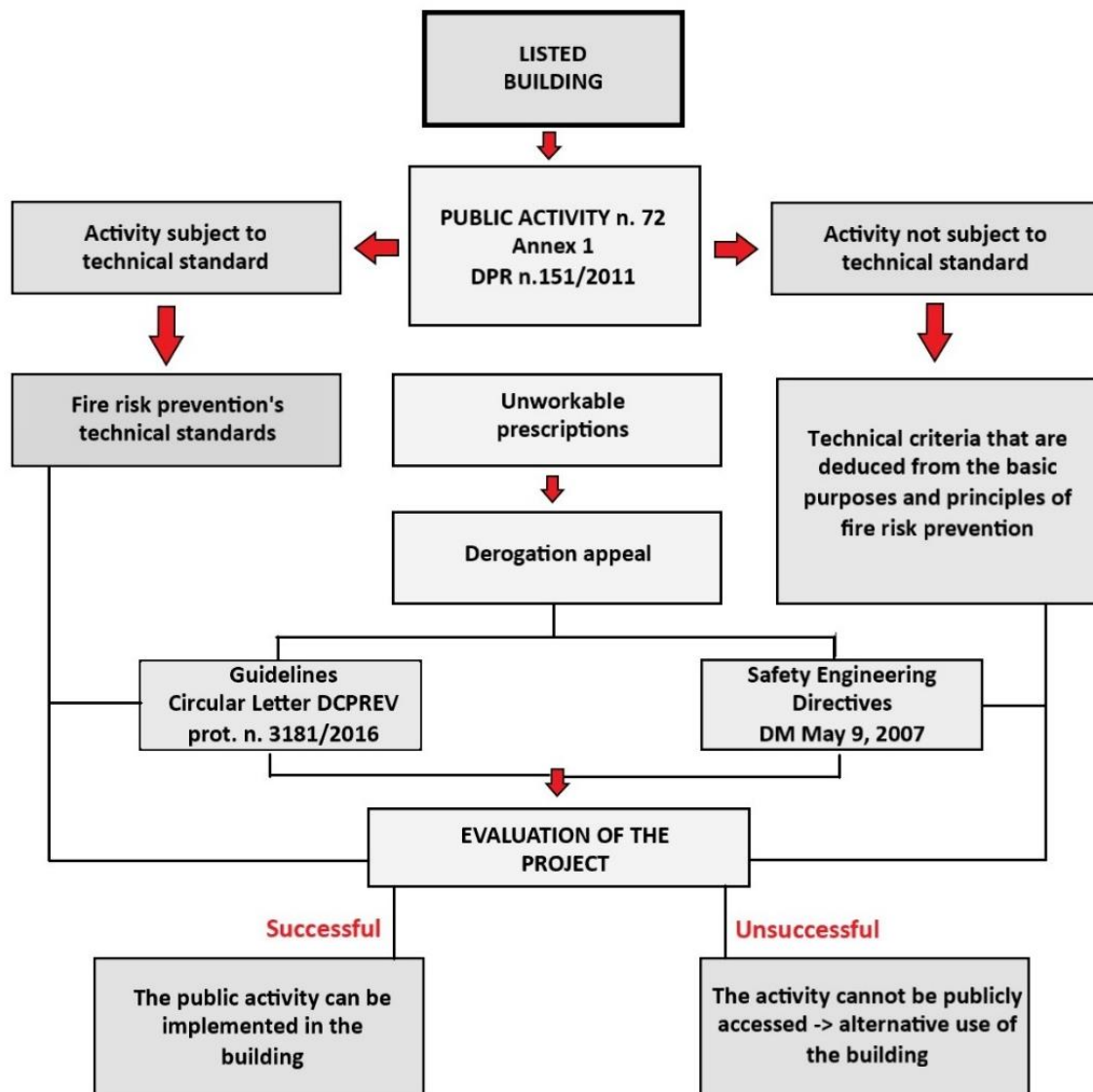


Fig. 6: Operational decision process concerning listed buildings in case of fire risk prevention (Source: 2016 Guidelines; Processing: Pompejano F., 2020)

The field of application of the 2016 Guideline includes the design of fire safety measures for buildings subject to protection, i.e. listed buildings. From a methodological point of view, the Guideline initially provides for the preliminary fire risk assessment (for the activities of the occupants and the protected objects/building). The latter must address issues related to:

- information for workers and other people involved;
- training of workers;
- the technical-organizational measures intended to implement the necessary measures and actions.

The Preliminary fire risk assessment is implemented in the following five steps:

1. identification of fire hazards;

2. identification of the protected assets/objects in the building;
3. identification of the activities that take place in the building;
4. identification of the number and characteristics of the occupants of the building;
5. classification of the fire risk level through the “*Rvita*” (risk profile relating to the protection of human life) and “*Rbeni*” (risk profile relating to the protection of assets/goods) risk profiles.

On the basis of the aforementioned fire risk evaluation, a fire risk prevention strategy is elaborated. This is based on not exhaustive but certainly useful to address possible design problems related to the fire risk prevention in listed buildings technical solutions (e.g. fire reaction, fire resistance, etc.). The integrated methodological approach suggested by the 2016 Guidelines implies a wide range of advantages, such as flexibility in the choice of the most appropriate design solution and consequently a more realistic definition of fire scenarios.

In listed buildings subject to protection in accordance to Legislative Decree 42/2004 and hosting non-regulated activities, the general criteria for fire risk prevention applies. The evaluation of such a project is preliminarily carried out by the territorially competent Provincial Command and, subsequently, by the Regional Technical Committees and the territorial bodies of the Ministry of Cultural Heritage and Activities and Tourism (MiBACT) for the aspects concerning conservation and protection issues.

B.3.4 Republic of Cyprus

In 2017, an amendment to the Streets and Buildings Regulations Law was issued in Cyprus (ΚΔΠ 248-2017-61HA and 61IA), concerning accessibility, safety in use and fire safety. For the latter, the amendment requires that all new structures can withstand their loads for specific time limits, that the spread inside and outside a building is limited, that the users can escape and be rescued and that the safety of the rescue teams is ensured (Annex IV (Regulation 61IA) Fire Safety (2017)). This is applicable to all buildings for which a permit was issued after 1/9/2020, but also to all existing buildings that are subject to alterations, repairs or strengthening interventions. For these buildings, in cases where it is not possible to adhere to the amendment, a comprehensive report must be submitted suggesting alternative solutions. Furthermore, proper structural materials, equipment and firefighting systems must be used, according to the provisions of Chapter 9 of the aforementioned Law. The following European standards are cited as references:

- EN ISO 13943 Fire Safety – Vocabulary
- EE 305/2011 Regulation for structural products
- EN 1992 Part 1.2 Chapter 13 (2003) Fire resistance indexes for structural elements of RC
- ENV 13381-4 and ENV 13381-9 Testing methods for the resistance of materials and passive protection systems under fire

Par. 1.11 refers specifically to historic buildings or listed monuments and states that the provisions of Annex IV are only applied to those parts of the building that are not related to its historical fabric, in such a way that they do not alter the historic character of the building. A special mention is also made in par. 3.16 (b) for the protection of buildings of crucial importance and collective use:

“3.16 B - Protection of architectural, historical and cultural values: Old and some new buildings of architectural, historical and cultural importance may have a value that cannot be measured moneywise. Their protection against fire damage is one of the most important moral obligations of the society. Historical structures, such as places of worship or sites of touristic interest, have a high value for society. In mechanical terms, the protection of cultural heritage does not differ from the protection of any other value. The regulation for fire protection must therefore be studied carefully”.

Despite this law, the Department of Town Planning and Housing, that is responsible for issuing building permits, follows only the instructions issued by the Fire Department, which usually suggest that concrete buildings are fire resistant and thus only specify that fire exits should resist fire for at least an hour. The Fire Department, in general, has a requirement that apartment buildings up to two floors and offices have a 30 min fire resistance, while higher or more important structures need at least one hour of fire resistance. This is considered to be fulfilled by concrete structures by default, while a report must be issued for timber or steel buildings. For the cases of existing buildings that do not change their type of use, there is no requirement for increasing the fire protection of the residents, by i.e. addition of fire exits. A minimum of smoke detectors and fire alarms are nevertheless required for the case of public buildings and offices. If a building is subjected to change of use and becomes a public space with increased occupancy, then the Fire Department requires proper escape routes, emergency lighting, exit signs, smoke detectors, fire alarms and a minimum of S1D0 for the materials used for insulation.

PART C: Energy Efficiency and Environmental Comfort

C.1 General recommendations

Sustainability – i.e. the ability to maintain the environmental, social and economic needs for the next generations -, is one of the key parameters determining today’s politics. The energy crisis, the emission of greenhouse gases and climate change have made it mandatory to seek for energy efficiency in buildings, that usually require more than 20% of the overall energy consumption budget of EU countries. Yet, for the case of historic concrete structures one must take under consideration the need to maintain the original fabric, the historic materials and features, when determining potential energy efficiency improvements. The usual strategies referring to new and existing structures are not always appropriate for historic structures, and again the proposed solutions must be issued on a case-by-case scenario, adjusted to the design, site orientation, size, shape, surrounding landscape and climate of each individual building. Furthermore, it is of crucial importance to define and maintain the inherent sustainable qualities of existing structures.

For the cases of historic concrete, the new architectural styles and novel materials introduced at the beginning of 20th century, with the high percentages of glazing in the total building envelope to provide natural ventilation and lighting, can be an important heat loss factor. Furthermore, original site orientation against northern winds or trees planted to shade or shield the structures may have been affected by the change of landscape, especially in the case of old structures which have become part of the city.

A preliminary assessment of the current conditions of a structure is the first step towards the effectiveness of possible solutions. For proper assessment, the R-values of the various components of the building must be obtained and the structure must be carefully examined for air and heat losses or thermal bridging. Also, a feasible goal must be set for the energy upgrading, that could result in up to 40% increase in energy efficiency, since setting up goals such as “zero energy” can result in significant alterations to the building fabric.

Some of the usual procedures adopted for upgrading the energy efficiency of existing buildings are not recommended for historic structures due to the potential alteration of their character. The solutions that are finally selected must be those that relate cost and energy saving efficiency with the minimum impact to the building. Table 1 provides examples of bad and good possible solutions for the energy upgrading of historic structures:

Table 1: Bad and Good practices for the energy upgrading of historic structures

Bad	Good
Replacement of historic window/doors	Repair of historic windows/doors (reduce infiltration around opening) Storm windows Weather strip doors and windows
Insulation in empty or visible materials, walls and cavities	Reduce air leakage. Draft proof (i.e. spray foam sealants) Seal gaps in the building envelope and add rigid foam insulation to the roof or attic
	Insulate basements
	Add insulation to masonry walls (more invasive)
	Install cool roofs and green roofs (more invasive)
	Use new glazed interior vestibules

Some additional recommendations have been presented by the 3NCULT Research Program on Efficient energy for EU cultural heritage [31]:

- Include sustainability requirements in renovation plans for historic buildings
- Use sustainable compatible materials
- Use locally produced compatible materials
- Consultation with researchers and the industry to find the optimal solution – traditional or innovative
- Adopt sustainable solutions (e.g. natural ventilation and daylight) - where compatible with building fabric
- Set standards for user comfort

The findings of the aforementioned research program, as well as several other guidelines, have been published within the last decades, show-casing completed projects of energy efficiency improvement in heritage buildings, including modernist architecture (e.g., the Guidebook of the Energy Efficient Architecture [32], the Green Monuments [33], etc.). In the case of modernist structures, the need for energy upgrading is sometimes even more urgent, than in the case of vernacular architecture, due to the existence of specific features (e.g. frame structure, thin envelope, large openings, cantilevered parts with thermal bridging, etc.). Even if the end-result is usually a compromise between the technical aspect of the improvement and the goals of heritage protection, such as authenticity of the materials and shapes, there are several examples of modernist reinforced concrete heritage buildings, which have been successfully restored, taking into account energy efficiency improvement demands: e.g., Paličkova vila⁵, Housing U Průhonu⁶, Husův sbor Vinohrady⁷. Last but not least, various measures for the use of alternative energy sources could also be adopted, like devices for solar, geothermal, wind or other sources of energy, that can help minimize fossil fuel energy consumption, without compromising the historic structure fabric [34].

C.2 Implementation of energy efficiency regulations in the 4 countries participating in CONSECH20 and practices used in historic concrete structures

C.2.1 The Netherlands

The applicable standards to determine the energy efficiency of new and existing buildings in the Netherlands are:

- NTA 8800_2018 [35] - Energy performance of buildings - Assessment method (Dutch Only)
- EN 15316 [36] - Energy performance of buildings - Method for calculation of system energy requirements and system efficiencies

There is no distinction between listed or non-listed buildings. Based on the experts consulted [37], currently the upgrading of the energy performance of existing buildings is not compulsory. What is mandatory is the issue of an Energy Label. However, this Label is not mandatory for monuments, according to the website of the Dutch Government [38].

C.2.2 Czech Republic

Legislation on energy efficiency in the Czech Republic aims at integrating the European regulations, albeit with a certain delay and in a complex way [39]. The principles of the energy efficiency agenda of

⁵ Green Monuments, <https://www.archiweb.cz/b/rekonstrukce-palickovy-vily>

⁶ Green Monuments
<https://www.stavebnictvi3000.cz/clanky/stavebni-upravy-bytoveho-domu-u-pruhonu-16-447-praha>

⁷ Green Monuments
<https://www.archiweb.cz/b/etapova-obnova-objektu-husova-sboru-architekta-janaka>

the Czech Republic are stated in the Energy Management Act [40] and in its implementing Decrees [41], deriving from the EU Energy Performance of Buildings Directives. The subject of energy performance and its improvement is also outlined in the Construction and Urban Planning Act [42] and its Implementing Decrees [43], but mostly in a general form and referring to other documents.

The energy performance and upgrading of buildings was introduced in the Czech legislation in the first decade of 2000. Since 2009, it is required for certain types of buildings to reach a specific level of energy efficiency. These requirements are getting stricter, following the implementation of new EU Directives. Since March 2020, it is required that all new buildings exceeding 350 m² of floor area reach the level of “nearly zero-energy buildings” (NZEB) [44].

The Energy Performance Certificate (EPC) provides details on the energy performance of buildings and its improvement with methods of assessment and classification, according to the European Model. It is compulsory to process the EPC for both new and existing buildings undergoing restoration and/or adaptation interventions, and when these are to be sold or let.

Energy performance adaptations in protected buildings in the Czech Republic follow specific rules. The Implementing Decree 268/2009 about Technical Requirements on Buildings, demands low energy consumption of buildings, in general, including protected buildings (provided the adaptation is not impracticable due to technical reasons [32]). However, the Energy Management Act No. 406/2000 Coll. considers the type of classification of buildings: cultural monuments or national cultural monuments, and buildings in Heritage Reservations and Heritage Zones are not required to reach any specific level of energy performance, but their energy efficiency improvement is encouraged.

The first massive programme for the improvement of buildings’ energy efficiency in the Czech Republic was launched in 2009 [45] and included subsidies both for the public and private sectors. In practice, the program led to the application of the following measures:

- (a) Upgrading of technical installations, e.g., heating and water boilers, heat pumps;
- (b) Upgrading of the thermal performance of the building envelope:
- (c) Additional insulation; and
- (d) Installation of new windows with double or triple glazing.

The implementation of this programme was processed very rapidly, and the legislation on heritage did not encompass such types of intervention. In the initial phase, there was no coordination of the program with the heritage protection authorities. Thus, there were no guidelines on how to implement the program measures on historic buildings; this caused many problematic interventions, both from a technical and aesthetical perspective.

The impact of the programme on historic structures was criticised by the National Heritage Institute, the Czech Chamber of Architects, and the Agency for the Protection of Nature and Landscape of the Ministry of Environment, who issued new rules for historic buildings (e.g. only partial additional insulation under the roof or on the back facade, or the replacement of windows by similar looking ones)[32].

The improvement of the energy performance of existing buildings in the Czech Republic is an issue of high importance; however, it is still debatable whether any efforts implemented have been well balanced with the protection of the architectural values of the buildings. The buildings listed as Cultural or National Monuments are protected from inappropriate interventions due to the special requirements of the licencing process. In the case of unprotected buildings located in protected areas (Heritage Reservations and Zones), though, the measures of protection are weaker, because sometimes modifications are being applied as part of repair or maintenance works, which do not require a special permission. Still, many experts [32] highlight that a high number of valuable historic buildings remain unprotected. The recent legislation has especially placed these valuable buildings under the threat of unnecessary and inappropriate interventions. Regarding modernist buildings, the situation can be even more complicated, because their particular values are not always clearly appreciated.

C.2.3 Italy

In Italy, the very first provisions on energy saving date back to 1976, with Law n. 373/1976 containing rules for the containment of energy consumption for thermal uses in buildings. However, Law n.10/1991 containing "*Rules on the rational use of energy, energy saving and development of renewable energy sources*" can be considered a milestone in the Italian legislative framework concerning energy efficiency and environmental issues. This Law replaced Law 373/1976 and, together with the two implementing Decrees (DPR 412/1993 and DPR 551/1999), constituted one of the main points of reference in this field thanks to its forefront contents, such as the subdivision of the territory into geographical areas with certain operating periods and climatic data, the introduction of the use of renewable sources (solar, wind, water, geothermal, wave/tidal energy), and the transformation of organic waste or plant products, as an additional tool to achieve energy efficiency objectives.

The Italian regulation of 2013 (Law 3 August 2013, no. 90. "Conversion into law, with amendments, of Decree-law no.63 of 4 June 2013, containing urgent provisions for the transposition of Directive 2010/31/EU, 19 May 2010, on energy performance in the construction for the definition of the infringement procedures launched by the EC") recommends building energy requirements, whilst the revised UNI TS 11300 parts 1-2-3-4-5⁸ recommends energy procedures for energy audits of buildings, considering the entire building system.

Nevertheless, the energy upgrading of existing historic buildings is more difficult, since the various measures are difficult to implement, especially in Italy, due to the strict regulation regarding the protection of buildings. In fact, for buildings subject to protection provisions according to Legislative Decree n. 42/2004 (Code of Cultural Heritage/Goods), the application of the rule is subject to compatibility with the principles of conservation and protection of cultural heritage. The energy retrofitting project of existing buildings often involves retrofitting interventions that raise questions from the conservation and restoration point of view. Therefore, it is very important to recognize that, compared to energy interventions/solutions on new buildings, energy retrofitting interventions on historic buildings need to respect the values of the building. The impact of any energy retrofitting interventions on historic buildings should therefore be minimum, in order to not affect (in a negative way) the historical, cultural, artistic values according to which the building has been listed.

Thus, a retrofitting project assumes a higher level of complexity when it concerns buildings that have a historical and cultural value, whilst at the same time it is essential that any intervention does not endanger the building itself. For the correct design of energy upgrading interventions, the preliminary study of the context within which a building exists, i.e. its surrounding, but also the condition of the building itself, including its state of conservation, its materials, etc., is of utmost importance. Therefore, in the fields of conservation, restoration, integrated refurbishment and retrofit actions, the scientific and professional debate is still open, especially because in Italy energy retrofit actions are often focused on modern buildings generally built in the 20th century, with poor energy efficiency characteristics. However, to-date, existing historic buildings and, in general, all buildings located in historic city centres, are excluded from achieving the minimum energy requirements following energy upgrading, due the importance of preserving the values according to which the building had been listed (D.Lgs 192/2005, Art. 3, comma 3 e 3-bis e 3-ter). Thus, there is a serious gap between the actual energy performance of historic buildings and the energy efficiency actions applicable to them. Recent Italian energy policies (DM 16/02/2016 "Update of the discipline for the incentive of small interventions for the increase of energy efficiency and for the production of thermal energy from renewable sources") encourage the public and private sectors to apply some retrofit actions through issuing tax reliefs and/or co-founding

⁸ They constitute the reference for the application at national level of the European Directive 2002/91/EC providing technical indications for the assessment of the thermal energy requirement and of the primary energy of buildings, also addressing the use of renewable energy.

those interventions. The energy classification in Italy has been updated by the government in October 2015 (DM 26/06/2015 “National guidelines for the energy certification of buildings”) and once again listed buildings are not included in the strict requirements enacted for all buildings. However, this is not a “tout court” exclusion. In fact, the provisions relating to the energy certification of buildings and the controls on heating systems remain valid, while all the others will be subject to evaluation by MiBACT bodies, that will have to assess, case by case, which interventions are feasible and which contradict the need for protection and conservation of the building. To this end, the *Associazione Italiana Condizionamento dell’Aria Riscaldamento e Refrigerazione* (AiCARR), i.e. Italian Association for Air conditioning, Heating and Cooling, issued in 2014 the Guidelines “*Energy Efficiency in Historic Buildings*”, providing information to evaluate and improve the energy performance of historic buildings, at the same time fully respecting their significance and values. Those guidelines were intended for engineers, architects and MiBAC superintendencies. The AiCARR Guidelines introduced the concept of “improvement” regarding both safety and comfort. Concerning energy, the Guidelines propose a procedure to follow in order to improve the energy efficiency of historic buildings. According to it, energy improvement means performing one or more interventions with the aim of reducing the energy performance index of a building, without changing its structural and architectural conditions, whilst trying at the same time to improve the quality of the environment. Figure 7 shows the flowchart of the procedure proposed by AICARR for the improvement of the energy efficiency of historic buildings.

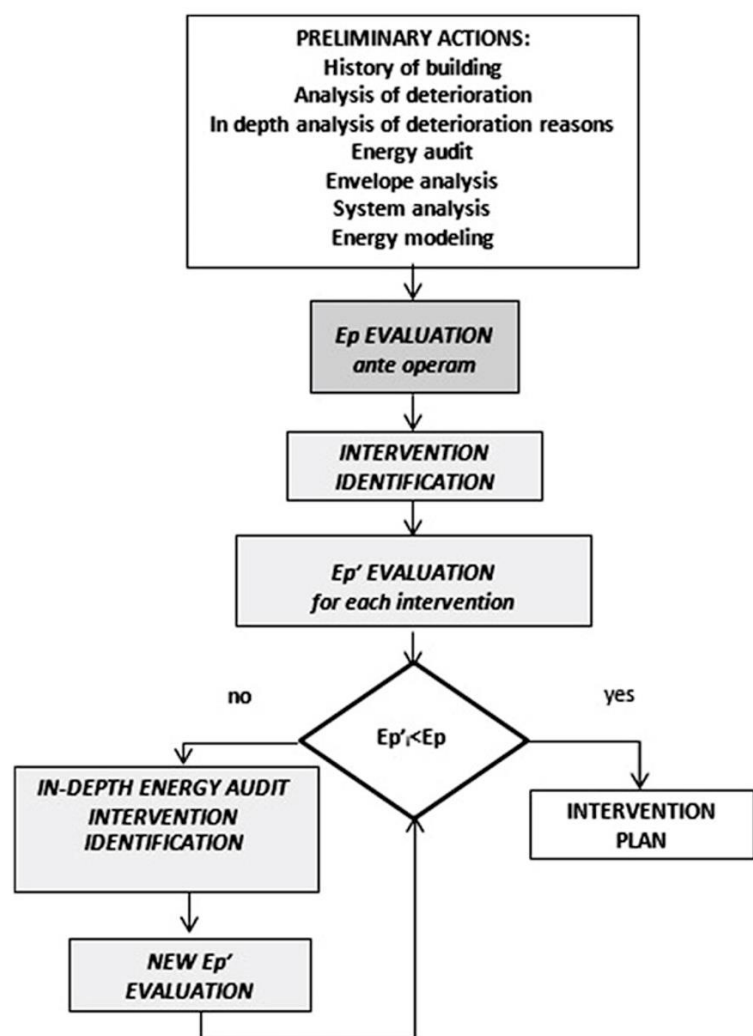


Fig.7: Procedure proposed by AICARR for the improvement of the energy efficiency of historic buildings. EP = Energy Performance (Source: Franco G. & Magrini A., 2017, 51)

C.2.4 Republic of Cyprus

The first Law regarding the energy efficiency of buildings in the Republic of Cyprus was issued in 2006 (ΚΔΠ 429/2006 – Ο περι Οδών και Οικοδομών (Ενεργειακή Απόδοση Κτιρίων) Κανονισμός του 2006). This Law listed some minimum measures relating to the energy efficiency of all new and retrofitted buildings with floor area exceeding 1000 m². These requirements, however, did not apply to listed buildings, as per (section 3.2):

“Buildings that are listed, or ancient monuments, are excluded in cases where conformity to the regulation would alter substantially, based on the judgement of the Town Planning Authority or of the Department of Antiquities, the character of the structure”.

The recent amendment Law of November 2020 (ΚΔΠ 121/2020) states that, in the event of extensive retrofit of existing structures, the building permit of which was issued prior to 1994, i.e. prior to the implementation of the Cypriot seismic code, these should comply with Energy Class A, and at the same time an Assessment Report for their structural integrity should be compiled. This report may be used to define the lifetime span of the building being restored *“based on the Eurocodes and in relation to the structural system’s current condition”*, and should be accompanied by recommendations concerning its structural upgrading/strengthening. This new practice of simultaneous seismic and energy upgrading aims at developing a holistic methodology for the restoration of an existing building, since the majority of existing building stock is both in danger due to structural under design, whilst at the same time it is energy consuming. Furthermore, the previous practice that only focused on the building’s energy efficiency has been leading to the hiding of structural problems and insufficiencies, and thus to a waste of resources on structures that could fail even during small intensity seismic events.

In this same amendment, listed buildings or monuments cease to be exempted from the obligation to have an Energy Performance Certificate when these are to be sold or rented, or when they are to undergo major alterations. Any exemptions must be properly substantiated with a report that states how these would significantly alter the historic fabric and those exemptions would have to be approved by the respective Conservation authority. The only buildings exempted from any obligation regarding energy efficiency are places of worship.

PART D: Summary

Table 2 summarizes the findings of this report with respect to seismic stability, fire safety, energy efficiency and environmental comfort in the 4 countries participating in CONSECH20 project.

Table 2 Summary of the SoA Report

		The Netherlands	Czech Republic	Italy	Cyprus
Seismic Stability	General Codes for retrofit	EC8-3, NPR 9998+C1	EC8-3, ČSN ISO 13822, ČSN 73 0038	EC8-3, <i>NTC2018</i>	EC8-3
	Practice for historic structures	The owner can choose the safety level of monuments, $IR \leq 10^{-5}$ criterion	Very stringent restrictions on possible interventions	If no measures are taken, then limitation of use is applied, based on safety levels	The owner can choose the safety level of monuments
Fire Safety	General Codes for fire safety	EN 1991-1-2, EN 1992-1-2, NEN 6069:2011	EN 1991-1-2, EN 1992-1-2, Fire Protection Act No. 133/1985	DM 03/08/2015	EN 1991-1-2, EN 1992-1-2, ΚΑΠ 248-2017-61HA and 61IA
	Practice for historic structures	No minimum requirements. The use is limited by the capacity of escape routes	Restrictions of use if safety requirements are not met	Royal Decree n. 1564, DM 20/05/1992, n.569, DPM 30/6/1995 n. 418, Circular letter DCPREV prot. n. 3181. Possibility of exceptions or alternative use, strict requirements when the building is to be open to the public	Minimum requirements only when change of use is to be expected. Special considerations (extensive measures) only when increased occupancy is to be expected.
Energy efficiency and environmental comfort	General Codes for energy efficiency	NTA 8800_2018, EN 15316	Directives 2010/31/EU, 2012/27/EU, 2018/844/EU	Law n.10/1991, DPR 412/1993, DPR 551/1999, DM 26/06/2015	ΚΑΠ 429/2006, ΚΑΠ 121/2020
	Practice for historic structures	No upgrading or Energy label necessary	Implementing Decree 268/2009, Energy Management Act No. 406/2000 Coll. Not required to meet any minimums	Not required for listed buildings, need for assessment of impact of interventions	Exempted from required upgrading only when properly substantiated. Energy Performance Certificate obligatory.

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