

ITALIAN ANTI-SEISMIC LEGISLATION AND BUILDING RESTORATION

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ABSTRACT

The study of the evolution of Italian anti-seismic legislation reveals the strategies and means of operating that have influenced and characterized the restoration of historical buildings in Italy.

This work looks at some of the most important steps in anti-seismic legislation from the unification of Italy to the present day, with the aim of highlighting how legislation reflects the technical culture of differing periods, influencing the work practices involved in the restoration of the historical building patrimony, and how legislation has slowly changed to incorporate a growing interest in the safeguarding and conservation of the historical and architectonic patrimony.

Safety legislation, in fact has often led to the incorporation of invasive structural elements that are out of place with respect to the original building tissue. In the first half of the last century, the impossibility of applying the models of modern science to stone buildings led to the transformation into frame-schemes through the insertion of new resistant structures. The 1908 Norms amended over time then led to the passing of Law 64/74.

The Law and decrees that followed have focused on new construction and only marginally on the problems linked to work on existing structures although the most recent decrees issued by the Ministry of Public Works have shown a growing

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awareness of this theme which is gaining more interest on a cultural and scientific level, introducing the concept of “upgrading” as an alternative to “anti-seismic retrofitting” and as natural means of acting on monumental buildings.

The most recent legislation includes the Ordinance of the President of the Council of Ministers n° 3274/03 and its amendments, and “Technical norms for construction” (Decree of the Ministry of Infra-structure and Transport n° 159 dated 14/9/2005), updated with the Decree of the Ministry of Infra-structure dated 14/11/2008.

Key words: Anti-Seismic Legislation, Building Restoration, Historic and Architectonic Patrimony, Evolution, Operating Means.

The Origins of Italy's Anti-Seismic Building Regulations

The strategic and operational procedures that have influenced and characterized construction works for recovering historic buildings in Italy can be identified by investigating how anti-seismic building regulations have evolved.

Limiting our investigation to the post-Italian unification period, the origin of this process can be assumed as the “Building regulations for the municipalities of the Island of Ischia, damaged by the earthquake of 28 July 1883”. Chapter III of this document sets out the regulations for the restoration of damaged or unsafe buildings; in addition to the demolition of vaults above ground, Art. 3 specifies that for the construction of suspended floors “if necessary, the box (casing) of the framing must bear on a sufficient number of vertical piers, suitably located within the thickness of the walls or at least in the corners of each room to be covered”. In the case of architecturally important buildings, Art. 3 also requires that “where vaults in churches might be in an unsafe condition, to prevent calamities these must be replaced by a correctly constructed ceiling bearing on vertical piers, which must either be interconnected or reinforced with metal ties” and furthermore that “should it be necessary to consolidate vaults or walls using iron ties or bands, these must spread over a large surface area by incorporating iron plates, grilles, long keys, or bars”.

The Ischia regulations were followed by others that were drawn up in response to specific situations such as those for the construction and renovation of buildings in the municipalities of Liguria hit by an earthquake on February 22, 1887, and those for the construction and restoration of buildings damaged by the 1906 earthquake in the provinces of Calabria and Messina. This localized process continued until Royal Decree no. 193 of the 18 April 1909 was adopted as a consequence of the 1908 earthquake in Messina and Reggio Calabria. This decree issued “Technical and sanitary regulations for the repair, reconstruction and new construction of public and private buildings in the places affected by the earthquake of 28 December 1908 and

other places previously listed in Royal Decree 15 April 1909, and as designated by their municipalities". Title III deals with repairs and ordinary building types, but also includes a series of criteria intended to bring existing buildings into line with the standards to be applied to new construction. Art. 33 requires that "Buildings that have been fissured and were not constructed using the timber frame and lightweight infill system above the ground floor, must first be reduced in height to comply with the preceding art. 30, and then reinforced using vertical supports in timber, iron, or reinforced concrete, firmly slotted and fixed into the foundations; these supports must continue to the top of the building, and be bound together by bands at the level of the foundation step and at the projections of the upper floor and eaves, so as to form a reinforcing cage. The vertical supports must be placed as a minimum, at all corners of the building, and in all cases not more than 5 m apart.

Consolidating bands must be connected to the beams of the suspended floor by extending one beam at least every 3 m and impaling it externally, or if this is not possible, by passing transversal anchors through the wall at a minimum of every 3 m along its length.

In single-storey buildings, if the wall thicknesses correspond to those set out in Art. 8 (sub-paragraph c) of these regulations, the reinforcing cage can be omitted on condition that all the other requirements set out in the preceding articles are complied with."

Another article in these regulations exempts buildings of architectural importance from the general requirements by introducing "case by case" criteria, stipulating that "in respect of the provisions of art. 3 above, the method for carrying out repairs consisting exclusively of consolidation, of buildings whose artistic, historical, or archaeological value bestows upon them national importance, shall be determined on a case by case basis".

The 1909 Regulations formed the basis for all legislation concerning buildings in masonry up until the early 1970s with the introduction of Law 64/74. All of the legislation up until that time [1] kept as a mainstay the "case by case" criterion for buildings of architectural importance and made cross-reference to laws concerning their safeguarding. In the case of ordinary masonry buildings these decrees and laws, with only minor changes, continued to require the framing system of vertical supports with consolidating bands at each upper floor and additional changes such as the replacement of staircases in masonry and cantilevered stairs, the elimination of thrust forces in roofs and vaults and the demolition of the vaults themselves if damaged or bearing on fissured or splayed walls or on buildings of more than one floor. Other requirements included the demolition of splayed or widely fissured masonry and the repair of smaller fissures with new masonry with mortar of good quality and solidly keying the new work into the undamaged part. The height of a repaired building was also reduced to that permitted for new buildings.

In decrees issued between 1924 and 1930 the materials used for framing buildings changed from wood, steel or reinforced concrete to steel alone, and in the 1935 decree to steel or reinforced concrete, with an increase in the permitted height of buildings from 10m to 16m. In practice, the 10m height limit had already become less stringent; a 1915 decree had in fact allowed the Civil Engineering Inspectorate to permit more than 10m if the static conditions were suitable.

Regulations in the 1980s and 1990s

It was not until the 1980s that significant and far reaching changes were made to anti-seismic regulations concerning the architectural patrimony.

The “Norm for the repair and reinforcing of buildings damaged in the regions of Basilicata, Campania and Puglia” [2] in 1981, followed by Ministry of Public Works Circular 30 July 1981 no. 21745 introduced, in fact the question of assessing the resistance of masonry construction to seismic action and anti-seismic retrofitting, to be achieved “by carrying out such works as will make the building able to withstand seismic action” [2] or as the guidelines specify, “by implementing such technical measures as will reduce the effects of seismic action and/or will increase the ability of the building to withstand such action, and restore the integrity of damaged structures” [3].

“This law did not take account of buildings of historic and artistic interest. When it was applied to them as it was to less important buildings in historic centers, it became evident that carrying out retrofitting work to important buildings would tend to disrupt their structural and architectural unity, because of the inherent nature of retrofitting” [4].

A growing awareness of the problem which began to loom large in cultural and scientific debates was reflected in the subsequent 1986 decree [5], which introduced the concept of “upgrading” as an alternative to retrofitting.

“Upgrading works are defined as one or more building operations carried out on individual structural elements of a building to render it safe whilst not substantially altering its overall behavior. Any localized construction works intended to renew or replace structural elements of a building must now be carried out within this definition.”

From this point onwards, so far as the fundamental objectives of repairing architecturally important historic buildings were concerned, this conceptual distinction between retrofitting and upgrading took on considerable importance.

In fact the 1986 decree went on to specify the situations in which the obligation to retrofit applies, for instance if additional floors are to be built; if a building is to be enlarged or restructured; and in all cases if the work would substantially alter its static and dynamic behavior. Since, by the nature of the historical patrimony, all such works would be incompatible, particularly as far as buildings of architectural importance are concerned, Circular no. 1032 [6] of the Ministry for Cultural Heritage, dated 18 July 1986, clarified that “the objective of carrying out works to make architecturally important buildings safe under seismic action must equate to upgrading”, concluding that whilst such works must effectively increase safety under seismic stress, the formal checks that ensure seismic action is taken into account at the design stage where new buildings are concerned, need not be inflexibly applied to historic buildings.

The same concept is reiterated four years later in Ministry for Cultural Heritage Circular no. 1841 dated 12 March 1991. This sets out that “from a technical viewpoint, upgrading would be the natural approach for works carried out on built complexes of historic/artistic importance situated in seismic zones”. [7]

The interpretations given in these two circulars find further regulatory consolidation in the Ministerial Decree of 16 January 1996, which newly defines the nature of upgrading by stating that “in particular, with respect to Art. 16 of Law 2 February 1974 no. 64, upgrading works to architecturally important buildings must be compatible with the requirement to protect and preserve cultural heritage”. [8]

In any case this approach had already been clearly set out in a ruling given by the High Council of the Ministry for Public Works, Section 1, dated 27 February 1992. Taking the same line as Circular no. 1032, this ruling stated that “... buildings of historic or conservation interest are not strictly subject to the discipline of the seismic regulations. However, since the need for safety is indispensable, construction works on such buildings must nevertheless follow seismic criteria even though these may differ from regulatory requirements. It follows that in studying the problem the designer of the works must make use of all the expedients that scientific knowledge makes available; so as to ensure safety should a seismic event occur... This is the approach that the regulations intend with regard to safety improvements”. [9]

It should also be considered that the regulations issued in the course of the 1980s and 1990s, along with the explanatory circulars that regularly accompanied them [10], enter more specifically than before into the details of the technological measures for carrying out building works. They do so either by imposing or suggesting the adoption of a series of criteria based on the current concrete technology and technical knowledge, which in practice however, often turned out to be invasive and alien to the historic method of construction of the buildings themselves.

A Ministerial Decree dated 3 March 1975 [11] made it compulsory to insert reinforced concrete ring beams in suspended floors, and to replace degraded suspended floors with new floors in steel or reinforced concrete, which were to be solidly embedded into the walls and anchored at their perimeter to edge beams or ring beams. Suspended timber floors were only permitted if justified by particular architectural considerations. A 1981 decree permitted masonry walls to be strengthened by injections of cementations or organic resin binding mixes or reinforced concrete; reinforced concrete roof slabs were to be made monolithic by including transversal reinforcement or welded steel mesh finished with cement render; reinforced concrete or steel secondary columns were to be incorporated into the structure, firmly toothed vertically into the main structural elements and connected to them at the ends; unevenly distributed openings were to be encircled with reinforced concrete or steel frames, connected to the adjacent masonry by reinforced perforations bored into the walls: existing arches and vaults were to be strengthened by bonding them to new arches and vaults in reinforced concrete.

Later decrees simply integrated these types of construction as technical upgrading of masonry buildings whilst adding a further requirement “Where it is necessary to reinstate or strengthen vaults, it is permissible to intervene by injecting binding mixes, preferably in conjunction with reinforced perforations.

In the case of vaults of a limited span, one valid strengthening system consists of constructing a load bearing shell, in general on the extrados, and fixing it to the existing vault using welded steel mesh spiked to the underlying structure to be strengthened, and completed with a layer of high-strength anti-shrinkage mortar or resin mixes” [12].

Recent Regulatory Provisions

Following the earthquake in Molise in October 2002, order no. 3274 of 20 March 2003, later amended and supplemented by OPCM (Order of the Prime Minister) 3431 of 3/5/05, resulted in the “Technical Regulations for the design, evaluation and retrofitting of buildings”. By making reference to existing buildings, these Regulations introduce the concept of safety testing as a means of acquiring useful information concerning a building.

In fact, it is the level of knowledge acquired that determines the analytical method, the mechanical parameters and the confidence factors that can be applied to the properties of building materials. In this regard Michele Calvi wrote “...ideologically speaking, the regulations introduce the basic idea that if secure knowledge is available concerning the characteristics of a building, it may be possible to predict with greater confidence how it is likely to behave, and may thus reduce the factors of safety that

are usually proportional to the degree of uncertainty with which something is known. This applies to structures but also to forces; in this case, to seismic forces". [13]

Another change concerns the definitions of "retrofitting" and "upgrading". Retrofitting still means imposing a certain level of safety and deploying any means necessary to attain it, but unlike before, upgrading now requires that "in all cases the sum of all the proposed works must be such as to confer on the building a greater degree of safety against seismic action."

For listed cultural buildings, for which work in any event is limited to upgrading, as provided for in sub-paragraph 4), Art. 29 of legislative decree no. 42/2004, "Landscape and Cultural Heritage Code," there is nevertheless still a requirement to calculate the acceleration levels of the ground that correspond to each critical state for the particular structural typology of that building, under existing conditions and upon completion of work.

Following on from Order 3274/2003 and the Technical Building Regulations referred to in Ministerial Decree of 14/9/2005, the "Prime Ministerial Directive for the assessment and mitigation of seismic risk to cultural heritage with reference to the Technical Building Regulations" was issued on 12 October 2007.

This Prime Ministerial Directive proposes "a knowledge-based analytical pathway in which the level of risk to which a building is exposed, or the suitability of carrying out particular works thereto, shall be assessed by comparing the foreseeable seismic action with the capacity of the existing structure to absorb it. This comparison shall be based on acquired qualitative and quantitative knowledge about the building. It may not be taken as definitive confirmation that the structural stresses caused by seismic action must necessarily be less than the ability of the existing structure to absorb them, but as one quantitative element to be taken into account along with others in arriving at a qualitative assessment that considers the overall needs of conservation, the intention to preserve the artifact from damage, and the seismic safety requirements in relation to the use of the building and its function" [14].

This Prime Ministerial Directive is aimed particularly at listed cultural heritage but also acts as a useful reference for historic buildings in general. It devotes considerable space to the criteria for seismic upgrading, specifically to reducing the extent of likely vulnerabilities by using computer modeling and observing existing damage. It indicates possible techniques for intervention, analyzing them critically in relation to their effectiveness and their impact on conservation in terms of non-invasiveness, reversibility, compatibility, durability, and cost. In this respect it has to be said that the Directive derives its content and its critical approach from the previous "Criteria for consolidation works to buildings in masonry" included in Attachment 2 – Buildings - to Order 3274 as modified by OPCM (Order of the Prime Minister) 3431 dated 3/5/05.

Both of the latter documents demonstrate a renewed awareness of traditional building techniques as well as of compatible innovative techniques that can be used together. Since the main task of any project is to produce a solution that takes into account a specific situation, these documents suggest adopting minimally invasive but effective techniques such as: inserting cross-ties at suspended floors and building ring beams around the tops of reinforced masonry walls; eliminating thrust in arches and vaults by means of traditional techniques such as chain ties, but also strengthening walls by constructing buttresses against them or locally increasing their thickness; timber-to-timber techniques for stiffening suspended floors and consolidating their bending moment; like-for-like replacement in wall construction; re-pointing mortar joints and inserting artificial bonds or transversal ties; and stabilizing timber roofs by interlinking them and interconnecting the tops of the masonry walls, the rafters, and the roof decking using construction methods and configurations that are compatible with local building traditions.

These techniques were incorporated into Circular no. 617 of 2 February 2009, which set out the guidelines for applying the “New Technical Building Regulations” approved by Ministerial Decree on 14 January 2008.

The 2005 Technical Regulations devoted little space to existing buildings, referring to the provisions of Attachment 2, Order 3274/2003 for application.

Due to the particular complexity of much of the existing building heritage arising from its physical vulnerability and its historic, artistic, architectural, and environmental value, and because of the difficulty of standardizing methods of testing, design, and the numerous traditional and modern building technologies available today, the updated 2008 Regulations take a performance-based approach, adopting a few general rules and making a number of important suggestions for correctly carrying out the various analysis, design, and implementation stages.

So far as masonry construction is concerned, these rules and suggestions also deal with the agglomerations of different types of buildings that are commonly found in historic urban centers. Building on the concepts introduced earlier in Attachment 2 to Order 3274/2003, the 2008 Regulations sets out criteria for identifying suitable sub-units of built fabric and for structurally analyzing these units in ways that take account the complex behavior of their inevitable interactions with other adjacent units, and the possibilities of simplifying the structural calculations.

A built agglomeration consists of an ensemble of parts as the final outcome of an articulated, non-unitary process of accretion influenced by numerous factors such as periods of construction, changes in the use of materials, changing needs, successions of ownership, etc.. These factors mean that analyzing any one building that forms part of such an agglomeration must take into account potential interactions due to its

structural contiguity with the adjacent buildings that are connected or adhere to it. With this in mind, the unit of built fabric to be structurally analyzed must be identified taking into account the forces potentially impinging on it from adjacent units. It must include cellular spaces that are interconnected by a common construction process both vertically and on plan. The analysis must take into consideration all the elements that will be affected by the transmission of all vertical loads to the ground, and must, if necessary, take in the whole agglomerate in order to identify the spatial connections that are of fundamental importance, particularly in respect of the context and the mechanisms of structural juxtaposition and superimposition.

But this structural unit must still be dealt with as part of a “case by case” approach that begins from analyzing the three-dimensional form of the built system of which it is a part and the quality and solidity of the new works proposed, whilst minimizing fragmentation of the unit into discrete parts of construction. By these means the designer of the new works will be able to define the minimum operational size of the structural unit; in some cases this may take in the whole ensemble of units of which the agglomeration consists, or may extend to even larger portions of the urban fabric as a whole [15].

Conclusion

Retracing these key stages in Italian anti-seismic regulations from the Unification of Italy until today highlights how regulatory requirements tend to reflect the technical culture of their time. The ways in which these regulations have evolved and how they have impacted on working practices reveal that there has been a sluggish but gradually increasing awareness of the issues that affect the protection and conservation of historical and architectural heritage. This growing awareness has also extended to include the ordinary historic fabric as well.

References

1. Royal Decree 6 September 1912 no. 1080 “approving the obligatory regulations for repairs, reconstruction and new construction of buildings in the municipalities affected by earthquakes, to replace those approved by Royal Decree 18 April 1909, no. 193”; Royal Decree 29 April 1915 no. 573 “concerning the technical and sanitary regulations to be met for construction works in the localities affected by the earthquake of 13 January 1915”; Royal Decree 23 October 1924 no. 2089 “Technical and Sanitary Building Regulations for localities affected by earthquakes”; Royal Decree 13 March 1927 no. 431 “Technical and Sanitary Building Regulations for localities affected by earthquakes”; Royal Decree 3 April 1930 no. 682 “New Technical and Sanitary Building Regulations for

- seismic localities”; Royal Decree 25 March 1935 no. 640 “New text of the Technical Building Regulations, with special prescriptions for localities affected by earthquakes”; Royal Decree 22 November 1937 no. 2015 “Technical Building Regulations, with special prescriptions for localities affected by earthquakes”; Law 25 November 1962 no. 1684 “Provisions for building works, with particular prescriptions for seismic zones”.
2. Ministry of Public Works Decree 2 July 1981, no. 593
 3. Ministry of Public Works Circular 30 July 1981 no. 21745 “Instructions regarding the technical regulations for the repair and strengthening of masonry buildings damaged by earthquakes”
 4. Calderini, C., Lagomarsino S. *L’ingegneria e le costruzioni storiche in Italia. Parte I. Sicurezza e progetto degli interventi di consolidamento* [Engineering and historic buildings in Italy. Part I. Safety and design of consolidation works]. *Atti del I° Convegno Nazionale “Storia dell’Ingegneria”* [Proceedings of the First National Conference on “Engineering History”], Naples, 8-9 March 2006, p. 675
 5. Ministry of Public Works Decree 24 January 1986 “Technical Regulations relating to anti-seismic building works”
 6. Ministry of Cultural and Environmental Heritage Circular no. 1032 (National Committee for the Prevention of Cultural Heritage from Seismic Risk, 18 July 1986) Specialized types of building works to architectural heritage in seismic zones: recommendations.
 7. Ministry of Cultural Heritage Circular no. 1841, 12 March 1991 “Directives for the preparation and execution of restoration projects, including maintenance and anti-seismic improvement works to architectural complexes of historical and artistic value in seismic zones”
 8. Ministerial Decree 16 January 1996 “Technical Regulations for construction works in seismic zones”
 9. High Council, First Section, Ministry for Public Works, Session 27 February 1992 “With regard to a question concerning the technical regulations to be applied in the design of construction works in masonry”
 10. Ministry of Public Works Circular 30 July 1981, no. 21745 “Instructions regarding the technical regulations for the repair and strengthening of buildings of masonry construction damaged by earthquakes”; Ministry of Public Works Circular 19 July 1986, no. 27690 “Ministerial Decree 24 January 1986. Instructions regarding the technical regulations for construction works in seismic zones”; Ministry of Public Works Circular 10 April 1997, no. 65/General Administration Office “Instructions for the application of the «Technical Regulations for construction works in seismic zones» in relation to Ministerial Decree 16 January 1996”

11. Ministerial Decree 3 March 1975 “Approval of the technical regulations for construction works in seismic zones”
12. Ministry of Public Works Circular 19 July 1986, no. 27690 and Ministry of Public Works Circular 10 April 1997, no. 65/General Administration Office
13. Bonino M. and Calderini C., La nuova normativa sismica e l'architettura. Intervista a Michele Calvi [The new seismic regulations and architecture. An interview with Michele Calvi]. *Parametro*, no. 251 (2004), p. 89.
14. Prime Ministerial Directive for the assessment and reduction of seismic risk to cultural heritage with reference to the Technical Building Regulations, 12 October 2007
15. Circular 2 February 2009, no. 617 – Instructions for the application of the “New technical regulations for construction works” referred to in Ministerial Decree 14 January 2008
16. Giuffrè, A. Cento Anni di Norme Sismiche Italiane [One hundred years of Italian seismic regulation]. *Ingegneria sismica*, Vol. 4, no.2 (1987), pp. 13-18.
17. De Marco, R. *La classificazione e la normativa sismica italiana dal 1909 al 1984* [The italian seismic classification and regulations from 1909 to 1984]. Istituto Poligrafico e Zecca dello Stato, Rome, 2000.