Reconsidering Urban Planning in Spain after the Lorca Earthquake (11th May 2011)

A. Aretxabala Díez & C. Sanz Larrea
School of Architecture, University of Navarra, Spain

SUMMARY
In Spain, building process in seismic-risk areas does not differ sensibly with building in non-seismic zones. A project must comply with a vast extension of standards and codes in constant revision. First Building Ordainment Law (1999) requires a Geotechnical Report to be included. Urban Planning decision-making is based on previous studies and flood-risk and topographic maps. Paradoxically, ground is considered as a land surface ignoring the volume under, whose characteristics in seismic risk areas are capable of increasing the power of seismic waves, like in Lorca. Urban regulations determine the building's enclosure without any seismic-resistant design criteria. However the real scenery of an earthquake is the city as a whole.

Keywords: Lorca earthquakes, Spanish Earthquake-Resistant Construction Standards, Urban Planning, Seismic Risk, Heritage in seismic Areas.

1. GROUND AND BUILDING STANDARDS

All the loads supported by a building structure are transmitted through its foundation to the ground, whose characteristics have a decisive influence on the value of the seismic action transferred to the superstructure. In Spain, in spite of this, those characteristics, compared to other variables involved in the design of a building (actions or resistant materials properties) were the most uncertain values considered, the only previous information usually based on former or similar experiences. This serious deficiency has been solved in codes and standards drafted recently in which soil characterization requirements have become increasingly more relevant.

1.1. Earthquake-Resistant Construction Standards: MV 101, PGS 1, PDS 1, NCSE 94 and NCSE 02

The Structural Concrete Code from 1939 was the first Spanish building standard. Design building actions, dead and live loads, and snow and wind actions, were defined two years later in Steel Use Restriction Regulations Article 2. Seismic action was not defined until the 1962 Building Actions Standard MV101, whose Seismic Risk Zoning Map of the Iberian Peninsula was based on the seismic intensity degree (Mercalli Scale) G > VII, VIII, IX and X. The map general information required "*further knowledge about ground properties, local geological structures, seismic active sources, focus and faults status and location*", in accordance to the importance of the building, recommending the consultation of local maps, drafted by the Geological Institute. A simplified design method for building was presented, assimilating the seismic action to horizontal static equivalent forces. These could be obtained multiplying the resistant elements' vertical loads by a seismic coefficient s_i, equal to the ratio between horizontal ground and gravity accelerations (Fig.1). This coefficient considered the influence of the structure type (frames or bearing walls), ground type (dense, compact or soft) and local seismic intensity degree. The map of PGS 1 Part A (1968), the first Earthquake-Resistant Construction Standard, divides the Spanish territory into zones A, B and C (Fig.2.a) depending on the seismic intensity G (MSK Scale): Low (A < VI), medium (VI < B < VIII) and high (VIII < C), its general information always to be completed when designing buildings of special importance. The seismic coefficient is more complex $s_i = C\, R\, \eta_i\, \beta\, \delta$, derived from seismic basic factor C (associated to a 0.5 second period T and dependent on G values), a seismic risk factor for 50 years R and foundation factor δ.

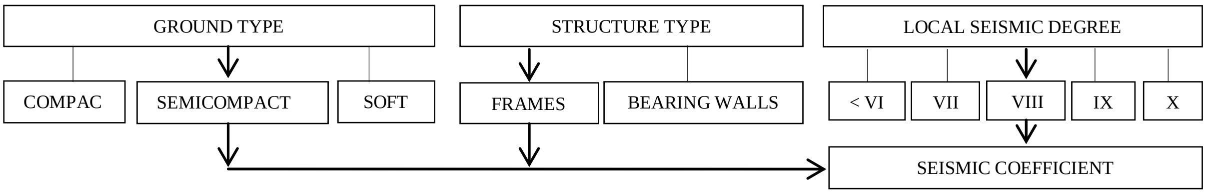

Figure 1. Seismic coefficient for buildings with reinforced concrete structure (MV 101)

The δ values depended on the ground type (I:Mud, II:Sand and gravel, III:Soft rock and consolidated sand and gravel, IV:Hard rock, and V:Very hard rock) and the structural foundation system (1:Friction Piles, 2:Tip Piles, 3:Isolated footings, 4:Continuous footings and 5:Slabs). Article 3.8 required the consideration of horizontal equivalent forces in the extreme of cantilever vertical elements ($s_c = 0.1\ C\ R + 0.20$) and normal to façade walls ($s_f = 0.1\ C\ R - 0.20 \geq 0$). Walls' maximum dimensions are limited in Article 4.3 (length $\leq$ 5 m, area $\leq$ 20 m^2, diagonal $\leq$ 100 times their thickness, inner cavity included) along with support conditions and anchorage requirements for partitions (on top, base and sides), parapets and vertical walls (top horizontal and vertical regularly distributed reinforced concrete elements, attached to structure or foundation). Width of adjacent buildings joints e (Article 4.1.3) must be greater than 2 cm or twice the addition of both building displacements Δ_i, with $\Delta_i = 25\ T_F^{\ 2}\ s_i$. The Structural Concrete Code EH 68 in force determined for the concrete for structural use a minimum compression stress of 12.5 N/mm^2 and for the steel, either smooth (the most commonly used until 1970s) or ribbed, a minimum steel yield strength of $f_{yk} \geq 240$ N/mm^2. In those days, supports of framed reinforced structures were designed with square cross-section pillars, at distances between 4.5-5.5 m, and girder beams with width equal or wider than them. Floor slabs were not conditioned to a minimum height, and the most usual was h_f =16-20 cm, with 2-3 cm top concrete slabs. Foundations, in absence of precise information on the ground, were usually over-dimensioned and executed with concrete of less compressive stress than the structure's (C 12.5 face to C 15/C 17.5).

Decree 462 on Project and Construction Rules enacted in 1971 emphasized that the design project must include information on the ground, so the architect in charge "*may require of the promoter, if necessary, a previous Ground Report*". However, promoters did not accept to bear this cost, and thus the only available information on the matter was the one derived from the execution of nearby sites execution or the architects own previous constructive experience.

The Permanent Commission for Seismic-Resistant Construction Standards was constituted in 1974, at the same time PDS 1, Part A substituted the former PGS 1. Its revised Seismic Risk Zoning Map maintains three zones (Fig. 2.b): First (G < VI), Second (VI $\leq G \leq$ VIII) and Third (G >VIII). In the latter "*it is required to consult additional local information for buildings whose destruction after an earthquake would disrupt an essential service or lead to catastrophic effects.*". The Seismic Coefficient changes to $s_i = C\ R\ \eta_i\ \beta\ \delta$. Structural response factor β is redefined and foundation factor δ values are adjusted. Regarding other aspects, the criterion to determine minimum width between adjacent buildings remained unchanged, but building displacement increased by multiplying the former value for a new factor k, (1.25 for braced structures and k =1.10 for unbraced). Requirements regarding partitions, cantilever masonry walls and facade walls were the same, but the Seismic Coefficients involved increased ($s_c = C + 0.20$ and $s_f = C + 0.10$).

In 1975, Spanish Technological Standard Foundations and Geotechnical Reports NTE CEG laid out the bases to draft Ground Reports, establishing the geotechnical campaign extent (function of site surface and building importance), the number of tests and results interpretation as well as the minimum content of the final report. One year later, NCSE 94 replaced PDS 1. Its Seismic Risk Map determined the Basic Seismic Acceleration characteristic values a_b (ratio between horizontal ground surface acceleration and g) for a 500 year return period (Fig.3.a) and the Ground Contribution Factor k. The Design Seismic Acceleration a_c can be obtained by multiplying the Basic Seismic Acceleration by a Risk Coefficient ρ (1 for residential buildings), adapting the return period to the possibility of an earthquake's recurrence and the building's importance and design working life (Fig.4).

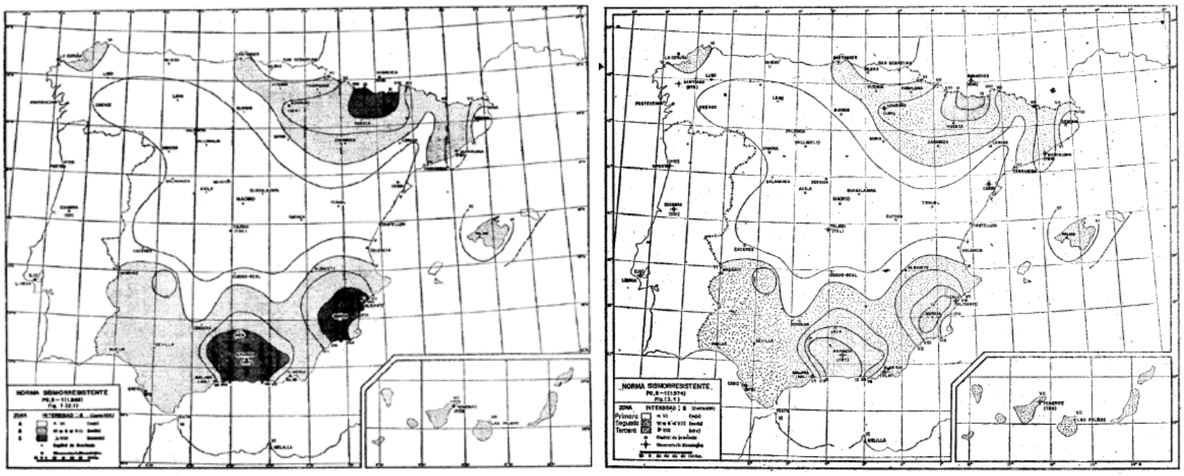

Figure 2. Seismic Risk Zoning Maps a) PGS 1 (1968) b) PDS 1 (1974)

New requirements for building simplified method were laid out (total height minor than 20 storey and/or 60 m on grade, supports continuity till foundation, without abrupt stiffness variations and regular geometric design and masses distribution). The Seismic Coefficient, $s_i = (a_c/g)\ \alpha_j\ \beta\ \eta_i$, was defined in function of the structure oscillation mode. The former five ground types for the determination of Ground Factor C were reduced to three (I Rock and cemented or dense granular: C = 1.0, II Cohesive medium to hard compactness granular: C = 1.4 and III Medium-loose or soft cohesive granular: C = 1.60). Ground characteristics must be determined, at least, to a depth under the foundation of 30 m. Article 4.14 states that façade walls and partitions, capable of developing stiffness and strength altering the structure's conditions (surprisingly named non-resistant elements) should be taken into account when developing the structural model for analysis and verified to comply with the correspondent design actions. There is no reference in relation to cantilever walls and the minimum buildings' joint width increases up to $e > 0{,}04\ (a_c/g)\ h$ cm. Article 4.4.1 General Criteria for Concrete Structures laid out requirements for low, high or very high ductility structures. With $a_c > 0.16\ g$, flat beams were forbidden; the dimension of the minimum cross-section for supports was increased to 30 cm and the minimum structural materials to C 20 concrete and B 500 N steel ($f_{yk} > 510$ N/mm^2). In other cases, according to the minimum general requirements of EH 91, the Concrete Code in force, C 12.5 concrete and B 400 N steel could be used. The minimum amount of beams and pillars reinforcement for high or very high ductility structures was increased, requiring $Ø_{min} \geq 6$ stirrups, with minor separation close to the joints. Undesirable short pillars (common in staircases design or under grade floors garages, to guarantee correct ventilation) and soft storey effects (frequent in ground floors for commercial use) were underlined, not specifying criteria to minimize the risk when it is inevitable in design.

The Spanish Basic Standards NBE CT 79 and CA 82 (Buildings Thermal and Acoustic Conditions) resulted in significant changes of the building constructive systems. Roofs and façades increased their thickness to incorporate thermal insulation (Fig.5.a and b), reducing the support base of the outer masonry sheet of façades walls and parapets. Floor slabs height increased up to 25-30 cm and their masses, correspondingly, increased. Consequently, architects designed longer floor slab spans with flat beams of the same height. To avoid thermal bridges, pillars cross-sections became rectangular, with the longest side aligned to the façade. All this reduced ductility derived from general design criteria regarding former reinforced concrete structures. On the other hand, Precast Concrete Code EP 77 mentioned for the first time computer-aided design for structures, widespread in Spain at that time.

NCSE 02 modified again the ground types:

• I	Compact rock, cemented soil or granular dense.	C = 1.00
• II	Highly fractured rock, dense granular or cohesive hard soils.	C = 1.30
• III	Granular of medium compactness, or cohesive firm to very firm consistency.	C = 1.60
• IV	Loose granular or soft cohesive soil.	C = 2.00

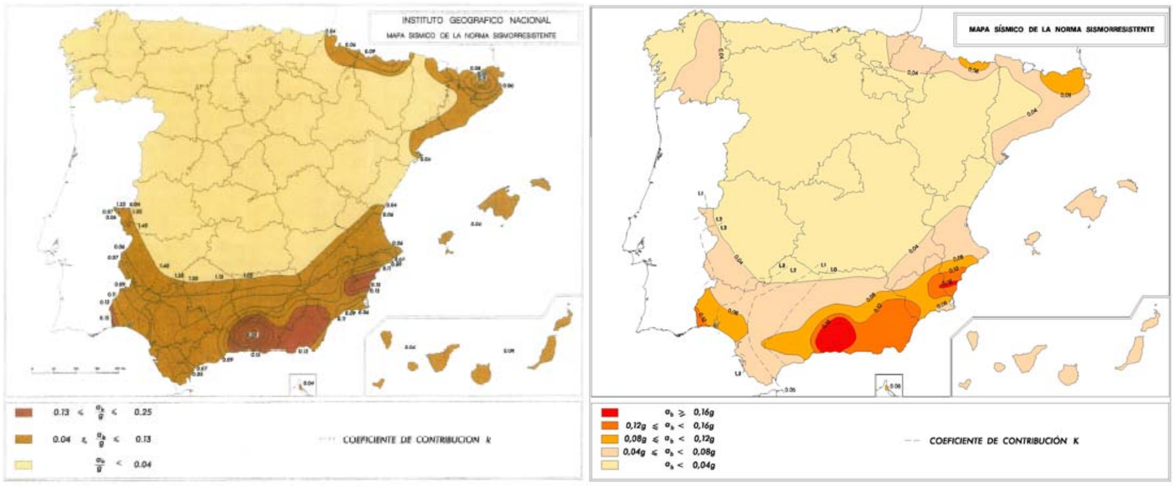

Figure 3. Seismic Risk Maps. a) NCSE 94 b) NCSE 02

Design acceleration $a_c = S\ \rho\ a_b$ could be obtained from the basic a_b (values according to a new Map, Fig.3.b), multiplied by the Risk Factor ρ and a new ground coefficient *S*, considering the amplifying ground effect due to its characteristics, responsible for the reduction or increase of the seismic action, values between 1 and *C*/1.25. In the simplified method, action combination in the main building planes requires a 30% increase in the seismic action considered in the normal plane. The significant increase of the structure cost derived can only be prevented by designing high or very high ductility structures, reducing the masses with floor slabs of minor height, girder beams instead of flat ones and increasing cross-sections of pillars. NCSE 02 underlines the need to reduce the economic losses and fatalities resulting from damage due to façade walls' and parapets' or sills' collapse in the event of an earthquake, but no specific measures to be taken to prevent it are detailed.

1.2 Other building codes and legislation. LOE and CTE

Article 4.1 of EHE, the 1998 Structural Concrete Code, determines finally the mandatory inclusion in design project of a Geotechnical Ground Report (GR), *"unless it may be incompatible with the nature of the site"*. Article 18 of Building Ordainment Law 38/1999 (LOE), stipulates that agents involved in the building process must be insured for any damage that compromises the strength and stability of a residential building. Given the importance of ground in this regard, Article 12.b states that the Proyect Manager is responsible for verifying the suitability of the foundation's structural system and the Promoter is responsible for facilitating the GR to the Designer. Thus, since 2000 including GRs as design project's Annexes was generalized. In accordance with the EHE, minimum resistance of structural concrete increased up to 25 N/mm^2. Minimun resistant steel, B 400 S, had been long before substituted by B 500 for economical reason, as well as diameter Ø6 by Ø8 for beams and pillars tranverse reinforcement. As a consequence of the gradual increase of cost damages due to excessive deflection of floor slabs, Concrete One-way Floor Slabs Code EFHE 2002 hardened their Serviceability Limit State requirements. Article 15.2.2 established a minimum height not requiring verification, whose values were even higher than those of the former Code, EF 96, which also established a minimum thickness of the top concrete slab of 4 cm, of great importance to improve the behavour of floor slabs in earthquakes.

Spanish 2006 Technical Building Code CTE meant the entry into force of the most extensive building standards review of all time. CTE Structural Safety Basic Documents (DB SEs) are Building Actions (DB SE AE), Foundations (DB SE C, with a section devoted to GR), Steel, Masonry and Wood Structures (DB SE A, F and M). None of them, nor NCSE 02, EHE 08 or EAE refer to safety assessment of existing structures. Other CTE DBs are HE (Energy Efficiency), HS (Health), HR (Noise), SUA (Safety of Use and Accessibility) and SI (Safety against fire), including details of façades/structure hardly compatible with the desirable behaviour of façades in seism. EHE 08 is a result of EHE review to adequate its content to CTE approach, adding also EFHE content.

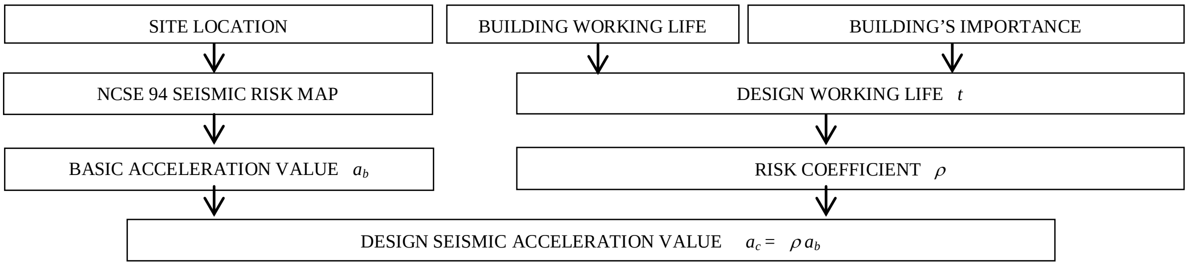

Figure 4. Relationship between Basic and Design Seismic Accelarations (NCSE 94)

High ductility steel SD (although being the most commonly used in earthquake-resistant structures years before) is presented and recommended in Annex 10, Special Requirements for Structures Subject to Seismic Actions. Chapter XIII of the 2011 first Steel Structural Code covering building and civil engineering strucrures, refers also to earthquake design of steel structures. CTE DB SE A is being revised to update its content to EAE and the whole text of CTE, for update.

1.3 Eurocodes: 8 Design of Structures for Earthquake Resistance and 7 Geotechnical Design

Parts 1, 2 and 3 of EC 7 (General Rules/Ground investigation and testing) and Parts 1 and 5 of EC 8 (General rules, seismic actions and building rules/Foundations, retaining structures and geotechnical aspects) are in force in Spain. Recently, a report on the proposal for UNE EN 1998-1 National Application Document, drafted with the collaboration of experts from Portugal, Italy and France, and having also analyzed working papers from other countries, such as Belgium and Germany, has been published. This report includes NCSE 02 Map, highlighting the urgent need to modify its content in order to adapt Basic Seismic Acceleration values to the maps of other countries around Spain, specifically in border areas like the Pyrenees (Fig. 6).

1.4 Standards for the rehabilitation of existing buildings

All cited standards and codes neither apply to the reform, rehabilitation or restoration of existing buildings (unless significant changes of the buildings' use or structure are designed) nor require them to comply with their essential requirements. CTE DB SE Annex D Structural Assessment of Existing Buildings is the only text on the matter. Inspired by ISO 13822:2001 (Bases for Design of Structures. Assessment of Existing Structures), its content is clearly insufficient from any point of view. In 2011 the Royal Decree-Law 8/2011 was enacted in order to promote building rehabilitation in Spain. Article 21 establishes a mandate to carry out Technical Building Inspections (ITE) of buildings with residential use, older than 50 years, located in cities over 25.000 inhabitants to assess their adequacy, among others basic requirements, to structural safety. Local Authorities are free to vary those conditions, if considered necessary in their territory.

2. LAND AND URBAN PLANNING LEGISLATION

Urban planning's concept of land differs significantly from the technical standards' and codes' concept of ground. Building design projects require detailed information of the geotechnical characteristics of a volume of ground up to a depth that increases in time, while urban planning takes into account only the surface characteristics of the land where cities are to develop, forgetting there is ground under which supports them, but also, in earthquakes, strikes and shakes them.

2.1 Spanish Land Acts: LS/1956, TRLS/1976, TRLS/1992, LS/1998 and TRLS/2007

The first Spanish Land Act (LS/1956), a confusing text drafted after other European land acts that followed the pioneering 1942 Italian Land Act, states that urban planning must be developed through a hierarchical system of urban plans, competence of Local Authorities and Civil Service, whose previous approval is required to build, develop or urbanize any area.

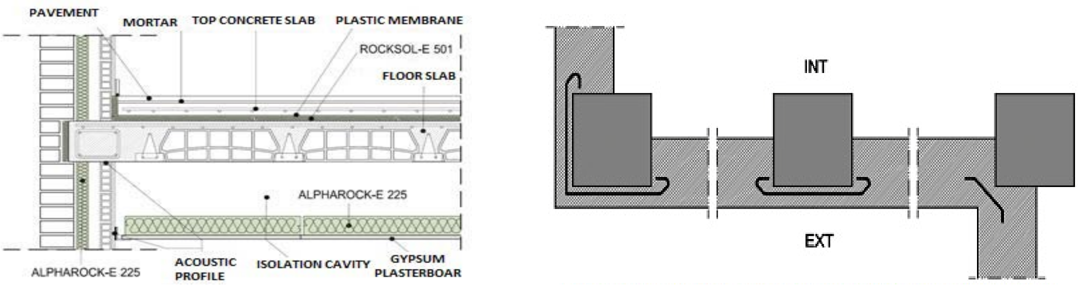

Figure 5. Constructive Details. a) Façade/floor slab. (Rockwool Catalogue) b) Façade/pillars (CTE)

Three Land Classes were set out for its legal status: Urban Land (qualified to be built), Reserve Land (land expected to become urban) and Rural Land (all the rest, not included in any of the other two, with 1 $m^3/5$ m^2 land-use coefficient). Each town's General Urban Plan must classify its land and provide detailed regulations for new building or rehabilitation or rebuilding of the existing: land use, alignments and grades, maximum volume (maximum storey number and total/per storey height) etc., defining completely the buildings' envelope. The Fist Land Act was reformed by Law 19/1975. Both texts became a new act, TRLS/1976, in which Rural Land was renamed as Non-developable Land, with no land-use coefficient. Land Classes remained invariable in TRLS/1992, till modified in LS/1998. Non-developable Land's concept was significantly amended and defined like the land including those areas unsuitable for urban development as well as the ones to be protected or preserved because of *"their natural, historic, archaeological, environmental or cultural values or accredited natural risks for urban development"*. Land Act TRLS/2007, in force since 2007, substituted Land Classes by Land Basic Situations, with two categories (Table 1): Urbanized Land or Rural Land (land to be *"preserved for cultural, ecological, agricultural, livestock, forestry and landscape values or natural and technological hazards, flood or other serious accidents risks"*). According to Article 10.c Land Management should *"serve natural hazards and major accidents prevention principles."*

2.2 European Framework Directives related to Urban Planning in Natural Hazard Zones

European Framework Directive 985/337/CEE for the Assesment of the Environment Effects of certain Projects (implemented into Spanish legislation by Royal Decree 1302/1986) requires the inclusion of an Environmental Impact Assessment in those projects. This document is a useful control tool, prior to execution, to prevent undesirable effects on the Environment. Directive 2001/42/EC (implemented by Law 9/2006), refers, in turn, to the environmental effects of Urban Planing, requiring the inclusions in Urban Plans of a Strategic Environmental Assessment. This environmental sustainability report allows the analysis of the direct, indirect or acumulative environmental effects of the different alternatives for urban development, becoming a useful tool for decision making prior to any plan's approval. In this respect, RLS/2007Article 15.2 states that the assessment *"must include a map of the area natural hazards"*, not detailing which are the natural risks to be considered. Directive 2007/60/EC on the Assessment and Flood Risk Management, derived from Water Directive 2000/60/EC (implemented by RD 903/2010), establishes a framework for assessing and managing flood risks, aiming to reduce its negative consequences for Human Health, Environment, Cultural Heritage and economic activity. This Directive obliges all European Union Member States to assess the risk of flooding in their territory, to develop hazard and flood risk maps and to draft flood risk management plans.

The activity of the Alhama de Murcia Fault (FAM) caused Lorca's eathquake on the 11th May, 2011. The only references to FAM in Lorca's General Urban Plan are contained in Volume XIV (Environmental Impact Statement, cited in the Geological Interest Points' list) and Volume I, where it is classified as a High Environmentally Significant Area. It is stated that FAM is *"one of the most active faults of the Iberian Peninsula, with constant earthquakes occurring along it, showing evidence of a constant tearing movement. This fact has a direct impact on works executed close to the fault's plane, like cracks that can be seen in the nearby Tajo-Segura Canal. Thus, it is a place of great educational interest (effects of active faults on human constructions)"*

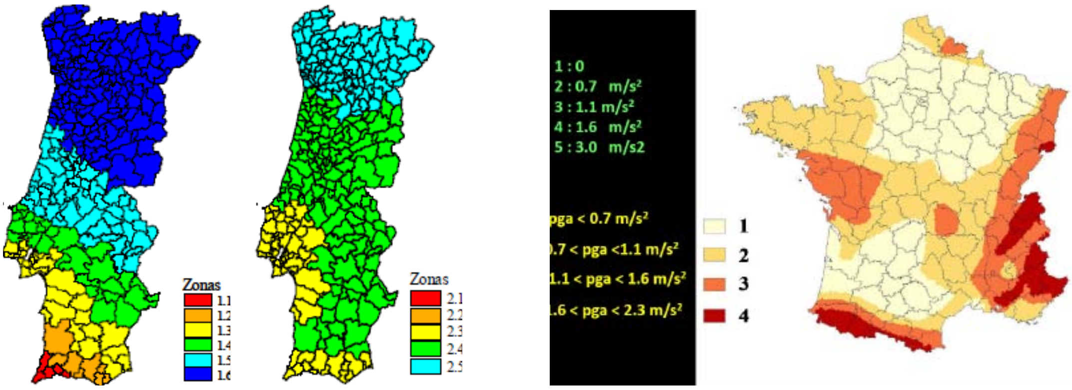

Figure 6. EN 1998-1 Eurocode 8 National Aplication Documents Seismic Risk Maps a) Portugal b) France

2.3 Heritage Protection Catalogs

Public Authorities are responsible for guaranteeing the preservation of Spanish Heritage, according to 1978 Spanish Constitution Article 46. Later on, Spanish Historical Heritage Law 16/1985 recognized that Spanish Heritage is a contribution to the Universal Civilization and stated that Public Authorities are responsible for its protection and enrichment, establishing different protection levels for heritage movable and immovable assets, highlighting the highest category of Cultural Interest Assets (BIC). Spanish regional Land Acts, drafted to complete the content of the state LS, regarding this matter, determine that to protect historical, cultural and architectural Heritage Sites and their environment, Town General Urban Plans must include a Catalog of such buildings and elements, along with specific protection measures, avoiding the destruction of this sites or their substantial modification due to urban development.

3. ANALYSIS OF THE 11th MAY 2011 LORCA'S EARTHQUAKE CONSEQUENCES

Lorca is a town in the river Guadalentín's valley, the third most important locality in the Spanish region of Murcia, in the Southeast of the Iberian Peninsula, with a population of 92.694 inhabitants (Spanish National Statistics Institute, INE, 2010). Founded by the Greeks, it is very well known for its architectural heritage, including a Castle (Declared BIC in 1931), its Historical Center (Declared National Historical-Artistic Ensemble in 1964) and one of the most important Baroque Ensembles of religious and civil monuments in Spain, which includes 13 churches rebuilt after the1674 earthquake. Maximum acceleration evaluated in the 2011 second eathquake's event, according to the information provided by the National Geological Institute (IGN), was 0.367*g*. A value exceeding the maximum expected on NCSE 02 (Basic Acceleration a_b = 0,12 *g*) and even highest values considered in articles on the matter, such as the 0.21 *g* basic acceleration value for Lorca of the revised Murcia Seismic Risk Map proposed by Buforn et al., after analyzing a former seism that took place in 2005 in Murcia .
Lorca's buildings can be classified into two groups, depending on their structural system: those with bearing walls (the older ones, including Historical Heritage buildings, most of the residential buildings in the Historic Town Center and self-constructed housing located close to the Castle and in the North of Lorca) and Reinforced Concrete (RC) frames structure buildings (residential buildings in North, East and West squares and almost all public use buildings), the number of steel frame structures being insignificant. The damage to the first group is a direct consequence of their morphology and structural type, with a deficient response to earthquake, due to low resistance to seismic action. Restorations of Heritage buildings (not included in any technical standard's scope) carried out in the 70s-80s, not only did not improve their structural response to seismic events but even worsened it significantly, due to the incorporation of high stiffness RC elements (Church of Santiago, Fig 7.a). In self-constructed housing, the greatest damage was located in the expansions in plan or height of the main building's volume, for obvious reasons. It should be noted that damage to residential buildings with bearing walls are significantly lower in those who have undergone partial reforms or rehabilitations and have proper maintenance, mostly located in the Historic Town Center.

Table 1. LS/1998 Land Classes and TRLS/2007 Basic Land Situations

LS/1998		TRLS/2007
LAND CLASSES	CATEGORIES	BASIC LAND SITUATIONS
URBAN	Consolidated	URBANIZED
	Unconsolidated	
DEVELOPABLE	Sectorized	RURAL
	No sectorized	
NON-DEVELOPABLE	To be protected	
	To be preserved	
	Inadecuate for urban development	

In relation to RC frame buildings damages, Table 2 presents the different values of the Seismic Coefficients and other factors obtained by applying the successive Earthquake-Resistant Construction Standards to a 4 storey building h = 15 m (maximum height considered in Lorca's General Urban Plan) and square floor plan l = 25 m, with RC structure and foundation (concrete, steel and types and dimensions of the structural elements most commonly used on the execution date taken into account). NCSE 02 came into force in 2004. Considering a period of 18 months for the construction of a building like the one to be analyzed, the percentage of existing buildings meeting their requirements struck by the 2011 seism was very low. Structural behaviour of the Lorca's buildings during the seism has been much better than the Italian's town of L'Aquila (Fig.7.c), where 50% of them were unusable, in comparison to Lorca, where, of a total of 6.417 buildings inspected, 4.039 (63%) were declared habitable, 1.286 (20%), without major structural damage and finally, 728 with serious structural damage and 329 to be demolished, totaling 17%. Structural damage of the more recent RC buildings (like the one that collapsed during the second event, built 10 years ago) was largely due to their incorrect seismic structural design (short pillars and soft storey floors, in most cases). A geographic viewer on building earthquake damages was habilitated in the Lorca Town Hall website, to help locating damaged buildings. The viewer shows that the earthquake was characterized by its directionality, following the FAM plan trace. A high number of buildings that had to be demolished concentrate in certain squares (La Viña, at the South West, and San Fernando, at Southeast). This fact cannot be justified by their structural type or construction date, so it may be attributed to the amplifying effect derived from the characteristics of the foundation ground in those areas. Foundations on rock would also explain why ruined buildings exempt façades in the upper area of Lorca, surprisingly, did not collapse during the earthquake (Fig.7.b).

Table 2. Seismic coefficients according to the sucessive Seismic Resistant Construction Standards

Standard	IN FORCE PERIOD (Years)	MAP: SEISMIC INTENSITY *G (C)*/ ACCELERATIONS a_c / a_b (cm/s^2)	SEISMIC COEFF. Hor. Forces s_{ik} ad	SEISMIC COEFF. Cantilever elements s_{ic}	SEISMIC COEFF. Facade walls s_{if}	MINIMUM JOINT WIDTH e (cm)	ANNEX GR	Increment s_{ik} %
MV 101 1962	1962 – 1969 (7)	G = VIII (Mercalli) General information, to complete	s = 0.0800	——————	——————	——————	No	——————
PGS 1 Part A 1968	1969 – 1974 (5)	G = VIII (MSK) (C = 0.1480) General information, to complete.	s_{1k}=0.1107η_{1k} η_{11}=0.33 η_{12}=0.66 η_{13}=1.00 η_{14}=1.20	0.2135	$-$ 0.180 $\geq$ 0 = 0	e > 2 $e > 2(\Delta_1+\Delta_2)$	No	38% (38%)
PDS 1 Part A 1974	1974 – 1997 (23)	G = VIII (C = 0.1500) General inf., to complete in special importance buildings	s_{1k}=0.1233η_{1k} η_{11}=0.33 η_{12}=0.66 η_{13}=1.00 η_{14}=1.20	0.3500	0.2500	e > 2 $e > 1.25(\Delta_1+\Delta_2)$	No	11% (54%)
NCSE 94	1997 – 2004 (7)	a_b= 0.11/g ρ = 1.00 $a_c = a_b\ \rho$ = 0.1100/g	s_{1k}=0.1065η_{1k} η_{11}=0.50 η_{12}=0.80 η_{13}=1.10 η_{14}=1.20	Accord. design action value	Accord. design action value	e>0.04(a_c/g)H= 6,6 cm IMPOSIBLE EXECUTION	Yes (min. depth 30 m)	-14% (33%)
NCSE 02	Since 2004 (8)	a_b= 0.12/g ρ = 1.00 S = 1.177 $a_c = a_b\ \rho\ S$ = 0.1407/g	s_{1k}=0.1759η_{1k} η_{11}=0.46 η_{12}=0.85 η_{13}=1.11 η_{14}=1.20	Accord. design action value	Accord. design action value	e > 3 $e > (u_1+u_2)$ $u=33\alpha_1(a_c/g)T^2_F$ = 1.17	Yes (min. depth 30 m)	65% (120%)

Figure 7. a) Church of Santiago damage, Lorca. b) Exempt façades in Lorca. c) Church in L'Aquila damage

Regarding this matter, the Guide for the Reconstruction of Demolished Lorca Buildings, drafted by the Presidency Ministry, states: *"In buildings' reconstruction, special care must be taken in relationship to the Ground Reports content, drafting them after having collected all data related to the site-work peculiarities and problems, Lorca's seismicity according to NCSE 02 as well as taken into account the new constructive recommendations of Lorca's General Urban Plan .... design projects containing among other annexes, the Geotechnical Report"*. Almost all the victims in Lorca were a consequence of the collapse of sills, parapets and panels of facade walls on the streets. The debate raised on the matter, revealed the existent confusion on their seismic-resistant character, even among architects, since NCSE 94 classified them as *"non-resistant elements"*. In September 2011, a set of new Urban Planning Complementary Regulations were approved by Lorca's Town Hall, with recommendations on earthquake-resistant design of staircases and basement floors structures (avoiding to include short pillars), sills and parapets (reproducing verbatim the text of PGS 1 and PDS 1 about them), façade walls (requiring a minimum support base of 2/3 the thickness of the outer masonry sheet), partitions or masonry facades of soft storey floor plans and cantilever vertical elements (to be braced to the main structure).To avoid captive pillar effects, joints between façade ground walls and are finally required.

4. CONCLUSIONS

When NCSE 02 was first published, critical voices arose considering its content disproportionate to the seismic activity in Spain. In May 2011, Lorca's earthquake was broadcast live on television and few months later, the eruption of a new underwater volcano in the Canary Island of El Hierro. Critics focused then on the need of reviewing NCSE 02. Lessons learnt from the earthquake must, obviously, lead to a global revision of NCSE 02, but, above all, to implement as many preventive measures as possible and not just corrective ones. This requires investing as much time and means as necessary to analyze in depth its effects, from any point of view. A few issues to study are proposed below.

In relation to Building Standards and Codes. The two key factors in Lorca, ignoring the fact that the seismic acceleration exceeded the one estimated in NCSE 02, were the number of victims in the streets caused by insufficient seismic-resistance of *"non-structural elements"* and the severe structural damages up to 1.000 million Euros due to seismic-resistant design criteria blunders in RC structures and bearing masonry walls Heritage. Spain has never had so many building standards in force. European standardization activity has a lot to do with it. ECs and Framework Directives have been the most important influences in the drafting of LOE and CTE, cornerstones of building standards. But standards' key gap regarding building rehabilitation, Heritage restoration and assessment of existing building's compliance to CTE requirements remains unsolved. On the other hand, there is a tendency to dispersion, duplication or standards content overlap (NCSE 02, EHE 08, EAE and EC 7 y 8 in relationship to seismic-resistant structural design) as well as inconsistencies among CTE DBs. Structural Codes language is becoming cryptic since it is translated from ECs English versions. Their content focuses on new concepts and design methods, not exposing the fundamental design criteria. The number of Codes Annexes tends to infinity. Therefore, dealing with a new structural code it is not an easy task for an architect. The behaviour of existing buildings, the architects' effectiveness in managing damages after the earthquake have shown the importance of the generalist character of the

Spanish architect, ultimately responsible for design and construction and thus capable of adopting the urgent decisions required after a seismic event. The question now is whether the urgent reinforcements may affect in a negative way the structural assembly behaviour, having modified so significantly the stiffness and resistance of certain elements. Another challenge is to create the right procedures to revise the compliance with newest Earthquake-resistant Construction Standards requirements of Public Use buildings (Lorca's Hospital had to be evacuated and there were no victims in schools because they were empty) as well as residential existing buildings in seismic-risk zones, for which ITEs could become a first approximation tool.

In relation to Urban Planning. TRLS/2007 emphasizes the need to ensure urban planning's future sustainability, from any point of view: economic, energetic, social or environmental. Lorca's earthquake is a reminder for Spanish urban planners of the fact that an earthquake's scenery is the city as a whole. In 1829, Torrevieja, a town close to Lorca, severely damaged in an earthquake, was rebuilt in a new location, not too far away from the original, but on a safer ground. In the XXIst Century, proposals of abandoning existing cities in seismic-risk areas are nonsense, but planning their urban development ignoring the importance of ground characteristics in an earthquake is unwise and irresponsible. A new approach on the matter is proposed, based on a transdisciplinary transference of experiences between building and Urban Planning. Since Ground Reports are required for designing a building, advantages of all types have been obtained: Cost of over-dimensioned foundations has been reduced; long-term buildings' structural safety has increased, reducing frequent pathologies due to foundations deffects, extremely expensive to repair. But it is still frequent to design single-family houses with deep foundations systems whose economic impact is unbearable for promoters and digging into rock to build underground multi-storey garages. In seismic risk areas, economy goes into the background, security of persons and their property becoming the priority. Not having a minimun information on the ground characteristics for urban planning may have consequences as serious as the demolition of entire squares, like La Viña and San Fernando in Lorca. In the latter, ground floors plans were designed consciously, for it is a flooding area. Building in flood-risk zones is unfortunately quite common in Spain. In 1996, an intense summer storm caused 87 victims in a campsite in the bed of a ravine in Biescas in a valley in the Pyrenees. Local Flood Risk Maps are being drafted as a consequence of the requirements of Directive 2007/60/EC. Lorca's experience should serve to adopt preventive measures in Spain before the UE requires it. Urban Planning in seismic risk zones should be based both on local basic geotechnical information on the ground as well as on local Seismic and Flood Risk Maps and earthquake-resistant city design criteria implemented, in order to guarantee not only that FAM will not be affected by urban development, but also, that urban development of those towns close it will be safe enough for the people and their property.

REFERENCES

Aretxabala, A. (2006). Conventional geotechnical collapsible soils tests variability. *Soil Engineering* **8:6**, 153-169.

Guevara Pérez, T. (2009). Modern Architecture in seismic zones. Gustavo Gili, Barcelona.

Guevara Pérez, T. et al. (2008). Short or captive column effect. IDEC, Architecture and Urbanism Faculty, Central University of Venezuela.

Lahuerta, J.A and Sanz, C. (1995). Seismic actions in building: NCSE 94. *RE Revista de edificación* **21**, 43-53.

Martinez-Díaz J.J and Hernández, J.L. (1991). Reactivation of the Alhama de Murcia Fault (Sector of Lorca – Totana). Kinematics and stress-field from the Messinian to the present. Geogaceta **9**, 38-42.

Michetti A.M. ,Vittori E. et al. (2009). Earthquake ground effects during moderate events: the l'aquila 2009 event case history *1st INQUA-IGCP 567 InternationalWorkshop on Earthquake Archaeology and Palaeoseismology. 7-13 September 2009 Baelo Claudia.* Abstracts Volume, 87–90.

MV 101-1962. Housing Ministry. Official State Bulletin (BOE) 35:1963/02/09, 2207-2225.

NCSE-94. Civil Works, Transport and Environment Ministry. Official State Bulletin (BOE) **33**:1995/02/08, 3935- 3980.

NCSR-02.Fomento Ministry. BOE **244**:2002/10/11, 35898 – 35967.

PDS-1 (1974) Part A. Development Planning Ministry. BOE **279**: 1974/11/21, 23585–23601.

PGS-1 (1968) Part A. Government Presidency. BOE **30**:1969/02/04, 1658-1675.

UNE EN 1998-1 Eurocode 8. Design of structures for earthquake resistance. Part 1. AENOR. Madrid.