The Lorca earthquake: Lessons for reconstruction

Given the extent of the damage caused by the Lorca earthquake, the scale of reconstruction required greatly exceeds the mere re-erection of its buildings. Major decisions respecting the urban model are called for, important decisions that will irreversibly condition the future of the city's population. The formidable challenge involved is to balance very disperse, at times abstract and always debatable criteria. That challenge, moreover, must be breasted with tools (some of the most common construction systems) whose performance during the quake proved to be unsafe.

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1. Introduction

In the afternoon of 11 May 2011, the earth around Lorca, a town in the Spanish province of Murcia, was shaken twice. Although the quake was of moderate magnitude, the proximity of its epicentre and its scant depth caused a brief but enormously violent surface tremor. The horizontal acceleration recorded, 0.37 g, was unprecedented in Spain.

As a direct result of the quakes, especially the second (with a higher magnitude than the first), many architectural elements, including roof parapets, façade panels and store front enclosures, fell off of buildings and onto the street (photograph 1). All the mortalities and the vast majority of the injuries were due to the impact of falling rubble.

(Photograph nº1)

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Rubble removal and building inspection and recovery were initiated immediately after the quakes. In a matter of a few days, decisions of major importance were made on the organisation of the reconstruction tasks, the results of which were visible very shortly thereafter.

Only weeks later, a large number of buildings were earmarked for demolition (photograph 2). Since many of the buildings affected were positioned side-by-side, the appearance of some neighbourhoods was soon substantially altered by the presence of vast empty lots. The outcome was more than the occasional gap between two buildings on a given street: whole city blocks disappeared. That process obviously led to profound urban transformation, with the redistribution of public and private spaces, the opportunity to build new municipal facilities, improvements in infrastructures and the like. A better city should arise from these ashes.

Nonetheless, some aspects of reconstruction have posed sizeable legal, economic, and in the final analysis political, problems. Striking a suitable balance among them all constitutes a considerable challenge that will determine the end result of the actions adopted.

Other considerations are purely technical and hence more limited in scope, although they also entail important issues because they determine the guidelines to be followed in new construction in seismic areas across the country. In a nutshell, answers are needed to apparently simple questions such as what should be done with roof parapets, which are so hazardous in earthquakes but so commonly found in Spanish construction.

The following account of our doubts about some of these particulars simply aims to emphasise their importance and the need to study them in greater depth.

(Photograph nº2)

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2. When to begin reconstruction

Less than two days after the quake, the city was immersed in frantic activity. A number of technical crews were provisionally bracing structures or proceeding to the preventive demolition of roof parapets. Others were taking note of the most visible damage to buildings and assessing their habitability, while yet others were clearing the rubble from streets and thoroughfares... At the same time whole families, including the children, were forming human chains to remove their belongings from their homes, some located in buildings that bore a black sign indicative of extreme hazard (in one case we witnessed, all the façade columns had collapsed: the building was demolished only a few days later).

Photograph nº3

Many streets were bustling with people, as shown in photograph 3. In others, people sat resting on sidewalk cafés... occasionally alongside masonry façades whose stability was precarious at best.

We could hardly believe our eyes. What would have happened if a major aftershock had occurred just then? Was such feverish, instantaneous activity truly necessary?

There is no simple answer to that question. In light of the moderate magnitude of the quake, possible aftershocks could have been assumed to be quickly attenuated. From that perspective, the extreme measures adopted just two years earlier in Italy on the occasion of the L'Aquila earthquake, which included closing the city off entirely for a few weeks, would not in all likelihood have been justified at Lorca.

While such extremes were certainly not necessary, we would have preferred greater control of pedestrian traffic. Everyone in Spain will surely remember the television footage of a church bell tower collapsing within inches of the cameramen. Was their presence there just minutes after the quake recommendable?

3. How to begin reconstruction

Photograph nº4

The core argument here is the same as in the preceding item. Decisions made in the name of speedy efficiency may lead to questionable results, particularly when such decisions are irreversible.

The fate of many of the buildings in Lorca was cast just a few weeks after the quake, and in a matter of months whole city blocks were demolished photograph 4), leaving certain quarters of the city woefully bare.

We are not persuaded of the need for such urgency. Demolishing a building does not necessarily mean that its former occupants will have a new home in less time. In fact, many of these plots remained empty for long periods before reconstruction got underway. Demolishing a building does, however, rule out the possibility of assessing possible alternatives, which in some specific cases would have meant conserving certain very worthy architectures. If only because decisions adopted on such a large scale put an end to a cityscape which, for better or for worse, reflects a period in history and a way of life, they should be weighed very cautiously.

4. What criteria to follow

In this brief discussion, we can do little more than list the headings under which we believe the criteria guiding reconstruction projects should be classified (Figure nº1).

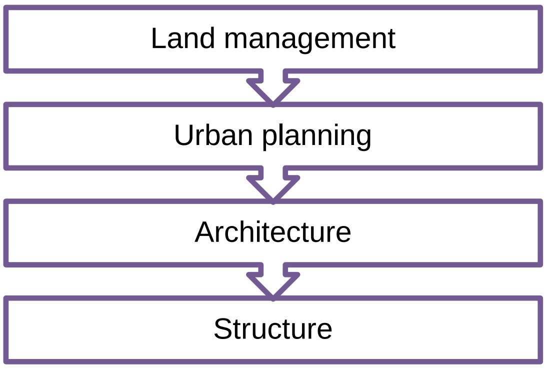


Figure nº1

4.1 Land managment

The first criteria to be borne in mind should draw from land management principles based on the region's seismicity. Envisaging the direction of urban expansion and ensuring earthquake-safe health facilities and effective communication constitute the most basic of preventive measures in areas where future quakes may be expected.

A full description and justification of such criteria lie beyond the scope of this article, which aims to address only the most elementary questions. Their importance cannot be overestimated, however.

4.2 Urban planning

Secondly (conceptually speaking only, no lesser importance intended), urban planning criteria must also be addressed. This is very likely the area that poses the most difficult decisions in any approach to urban construction.

We would have to decide, for instance, whether we are willing to change our cityscapes and ownership distribution in cities, along with the legal system by which they are governed and many other matters. Quite a few of those proposals, moreover, could well be interpreted to constitute inordinate legislative demands that run counter to what we have come to regard as tradition.

A simple example may illustrate this idea. All our cities are organised around a similar pattern: buildings are grouped by blocks flanked by streets whose uniform fronts characterise our urban scenery. Each new building is erected alongside the existing ones, while the successive editions of earthquake-resistant construction codes have failed to impose the minimum space necessary to prevent pounding between adjacent buildings or even between their façades. The result is severe risk of collapse of whole panes of masonry (photograph nº5) if a quake does strike.

In countries with greater seismicity, such a situation is unimaginable. A simple stroll (albeit virtual, with the aid of on-line street views) along any street in Japan reveals a very different sort of zoning. All the buildings are detached and set at distances which, while solving the seismic problem, do not always afford an elegant solution for the intermediate spaces: splendid buildings are often skirted by unseemly alleyways.

Theoretically, Spain's fairly moderate seismicity would allow for intermediate solutions, maintaining the formal continuity of street fronts while at the same time leaving the space required to ensure each building's independent response to earthquakes. In practice, however, this is a matter that not only remains unsolved, but in fact is not even addressed: each new building is built directly against the one standing adjacent to it (photograph nº6)

Photograph nº5-6

In a word, the structural logic that should condition urban planning regulations is subordinated to convenience of construction, economic considerations (although in the long term a poorly effected inter-building structural joint is not necessarily less expensive) and, far too often, to mere tradition (construction is not a particularly innovative industry).

Urban planning ordinances, in turn, seldom regulate specific matters not included in higher level legislation. While structures such as property walls (photograph nº7) are often a municipal requirement, local ordinances fail to establish reasonable construction solutions that would prevent their collapse during an earthquake. Such walls are frequently built with heavy masonry that constitutes a high risk not only under accidental loads, but even when exposed to simple wind action.

Photograph nº7

While the country is obviously not in a position to require formal architectural designs to guarantee the safety of walls around each and every property (standard procedure in other countries), the number and severity of the incidents involving these walls (particularly during wind storms) are alarming. The collapse of a wall of this nature caused a mortality in the Lorca quake.

One healthy exercise that we would recommend to the patient reader is to calculate the dimensions (and respective cost!) of the footing needed to meet wind action requirements in walls such as called for by many local ordinances.

We could naturally describe other circumstances relating local ordinances to building performance. Requirements that call for much greater minimum heights in store fronts than in other storeys favour the formation of soft storeys. Accessibility requirements may generate short columns, as the solution is for the stair carriage under each flight to rest on the columns...

By way of summary, the mere (yet inevitable) publication of new regulations entails certain risks. As a result of the minimum ground storey height requirement, for instance, the floor slabs in buildings erected after its entry into effect stand at a different elevation than in adjacent buildings built before that time. Under such circumstances, the consequences of earthquake-induced pounding are much more severe.

4.3 Architecture

A third group of criteria covers architectural elements, broadly defined.

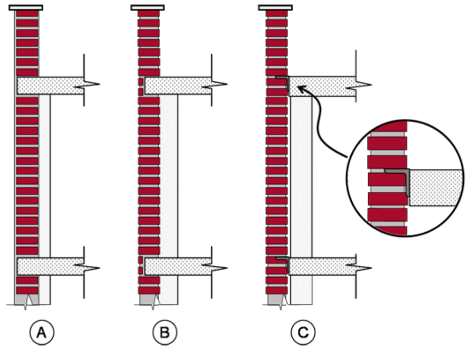
One of the major lessons learnt from the Lorca earthquake was how important these (at times inappropriately labelled) "non-structural" elements can be, in particular the masonry in enclosures, partitions, stairways and floors.

Enclosures pose a problem for which no suitable solution has yet been found in Spain, in our opinion. In the vast majority of buildings, they consist of facing or rendered brick.

The problem posed has to do with the interaction between each masonry pane and the structure to which it is attached.

The sole variable in the standard construction arrangements in Spain shown in Figure 2 is the position of the masonry with respect to the floor slab. Since the nineteen fifties when the panes rested fully on the slab (Figure 2 A), other solutions have been developed, such as the partially supported façades (Figure 2 B) often seen today, and attachment to steel brackets (Figure 2 C). A variation on the third approach, very common when the pane is not upwardly continuous, consists of securing the bracket to rods hung from the floor slab (Figure 3 and photograph 8)

Figure nº2



This wholly inappropriate solution, unable to resist any horizontal action, was used in many of the roof parapets that collapsed during the Lorca earthquake. The severest problem, however, is that this is not the only hazard.

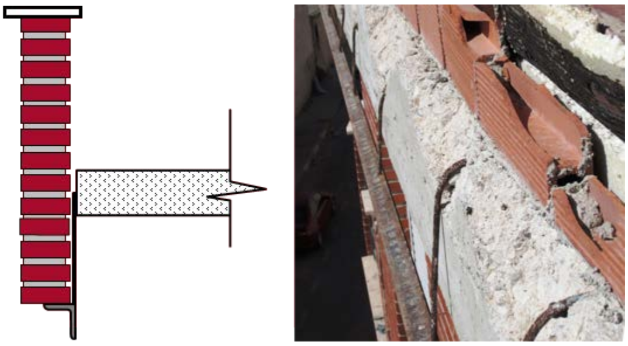


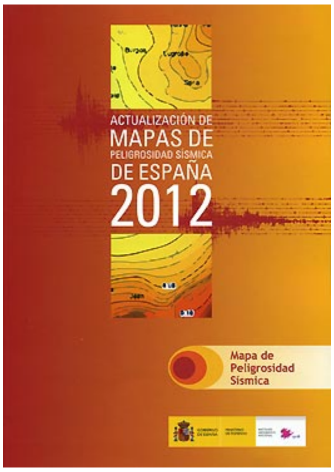
Figura nº 3 y Fotografía nº 8

Actually, none of the arrangements depicted in Figure 2 (which illustrates the construction set-ups used in practice) can guarantee pane stability when exposed to the minimum horizontal actions defined in construction codes.

The situation described is merely one of the aspects of the underlying problem, however. Today's construction systems on the whole do not guarantee that architectural elements will meet the *minimum resistance requirements laid down in the legislation*.

This, in our view, is one of the most important issues posed in connection not only with reconstruction in Lorca, but with the erection of new buildings anywhere in Spain. Buildings have traditionally been regarded as safe when their structure is safe. Lorca showed how mistaken that assumption is. A safe structure does not suffice: elements such as façades, stairways and parapets must also be safe, but are very seldom designed to safety requirements.

4.4 Structure



Last but not least is one final heading under which we would classify reconstruction criteria: structure.

The first of the many problems posed by structure lies in design loads. Although a new seismic hazard map (Figure 4) has recently been published, it is not as binding as it would have been had it been included in earthquake legislation. This new map raises design acceleration values substantially in many areas of the country (Table 1)In one extreme but highly significant case, the city of Barcelona, design stress has trebled.

(Figure 4)

	NCSE-02	**2012**	**Δ**
LORCA	0.12	0.23	1.85
MURCIA	0.16	1.27	1.74
BENIDORM	0.09	0.19	1.99
VALENCIA	0.06	0.14	2.29
BARCELONA	0.04	0.12	2.79

(Table nº 1)

While those numbers are in themselves dramatic, they are indicative of much more significant change, because they involve a shift to higher design load brackets. In large areas of the country where seismic design was not formerly mandatory, structures will now have to be built to resist fairly severe earthquake action.

That in practice will call for changes in the most common building systems.

Certain basic features of the structure itself will have to be revisited, beginning with the traditional controversy between (normally portal frame-based) flexible and (shear wall-based) stiff structures.

Portal frames are the standard arrangement in conventional buildings, essentially because such designs artificially reduce loads. Inasmuch as this parameter is derived from periods calculated with modal analysis of the bare structure, which are much higher than the building's periods, the equivalent loads are misleadingly low, lightening construction costs.

That, of course, leads to structures that are so flexible that, as the Lorca experience showed, they bear absolutely no load because stress is supported by the much stiffer enclosures and partitions.

Structures designed to such criteria are in fact absolutely pointless.

Among many other problems, this approach clearly entails forfeiting the ability to control damage to partitions and enclosures (photograph 9).

Photograph nº9

The new code will presumably delimit such excesses by imposing some manner of ceiling on relative inter-storey displacement, a provision in place for many years in other countries.

Another question that we believe the new code should address is the very definition of bearing systems.

When a structure is defined as a portal frame the high ductility it can be attributed artificially lowers design loads. The mere presence of floor slab hoops or joists does not constitute a portal frame, however; nor may beams in such structures be discontinuous, out of the theoretical plane that would contain the portal frame, or consist of header or soffit beams.

Structural systems are often labelled too leniently to capitalise on advantages that are actually only afforded by systems that adhere strictly to the category definition. The specifications for ductile portal frames laid down in the legislation are not normally applied.

Conclusions

In Spain seismic threat is usually regarded as little more than a legislative imposition of scant consequence, despite striking evidence to the contrary.

- The country's seismic record in recent years culminated with the Lorca earthquake but includes other events in the area whose magnitude was not much lower.
- A seismic hazard map has recently been published that not only multiplies design load requirements in zones formerly regarded to be at risk, but enlarges the areas covered considerably. According to prevailing opinion, the new map is a direct consequence of the Lorca quake and its formulation was conditioned by the difference between the acceleration envisaged for the city in the codes and the much higher value actually recorded. In fact, however, the map was being drawn up when the earthquake struck and was not overly impacted by that event.
- Certain Increasingly explicit opinions detected anomalies in the former map, which showed a clear discontinuity between the stress values defined in Spanish and neighbouring countries' legislations. The contrast was particularly acute in certain areas of the Pyrenees, where the design acceleration in France was several times greater than in Spain.

Designing for seismic hazard would, then, clearly appear to be necessary. The problem as we see it is that the country's construction systems are not presently prepared to accommodate that requisite.

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