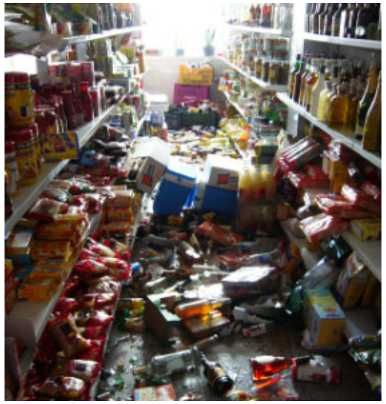

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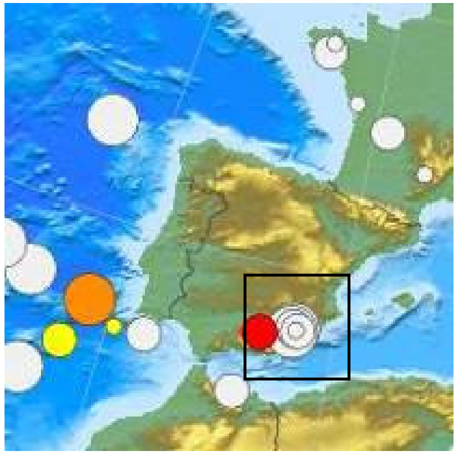
FIELD REPORT FOR THE JANUARY 29TH 2005 EARTHQUAKES IN LORCA, SPAIN

1 Executive summary

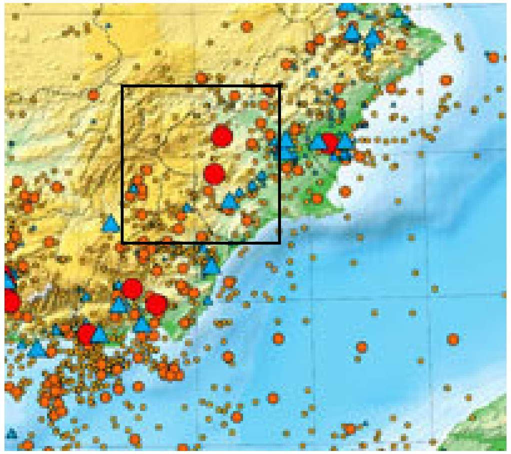
On 29th January 2005 a moderate earthquake of 4.8 M_w (IGN) marked the start of the second seismic swarm in the last two years in an area near the Sierra del Cambrón fault, affecting various towns near the city of Lorca in the south-eastern corner of the Iberian peninsula. A maximum intensity of 7 EMS is assigned to the town of Zarcilla located on a sandy clay quaternary sedimentary basin a few kms SW of the supposed fault. Other locations surrounding the source at similar fault trace distances were assigned values ranging between 5 and 6 EMS, suggesting amplification of ground motion at Zarcilla on account of local conditions.

1.1 Methodology

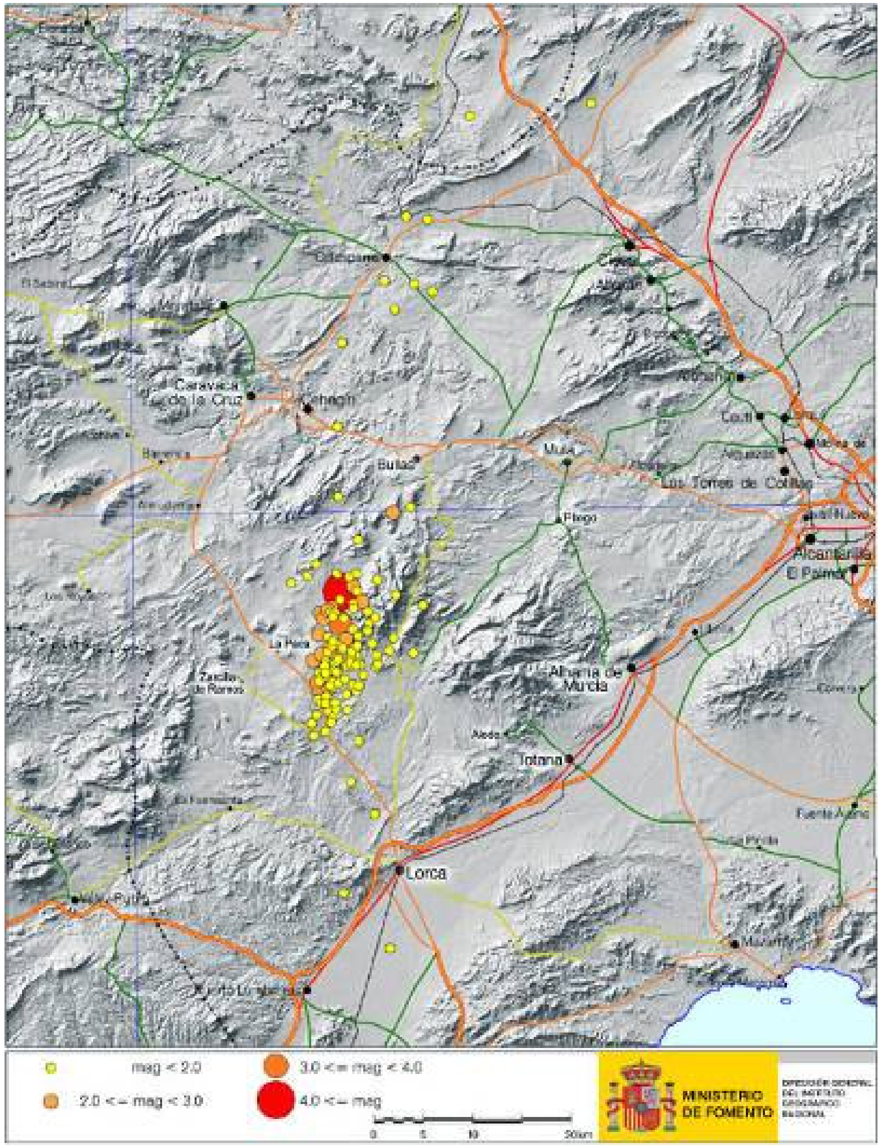
Field reports were conducted hours after the first shock between the 29th and 30th January and again between the 4th and 6th of February after the second main event of 4.3 M_w (IGN) on the 3rd February and finally between the 11th and 13th February. Buildings were surveyed, photographed and surrounding areas inspected for seismigeological effects. Observers were questioned and interviewed with EMS intensity evaluation in mind.



CSEM 14/02/05



IGN seismicity >3.0



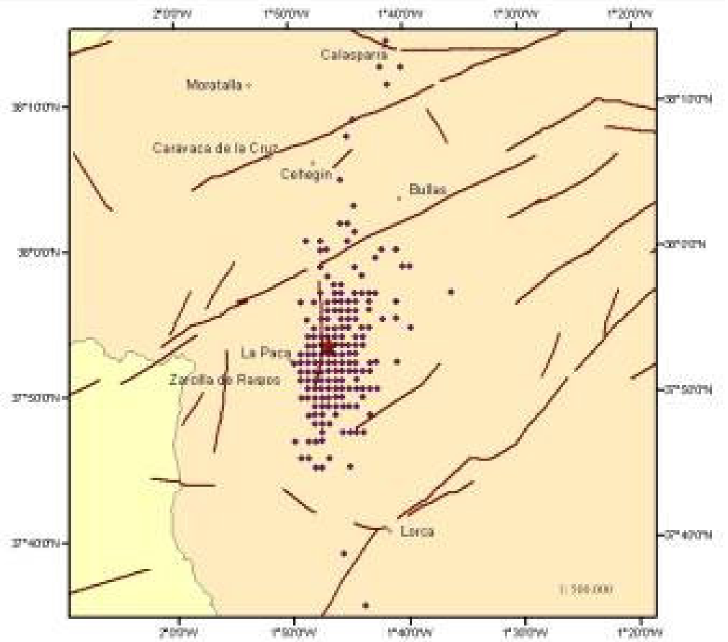
Epicentral locations for the 2005 series up to 04/02/05 (IGN)

2 Background information

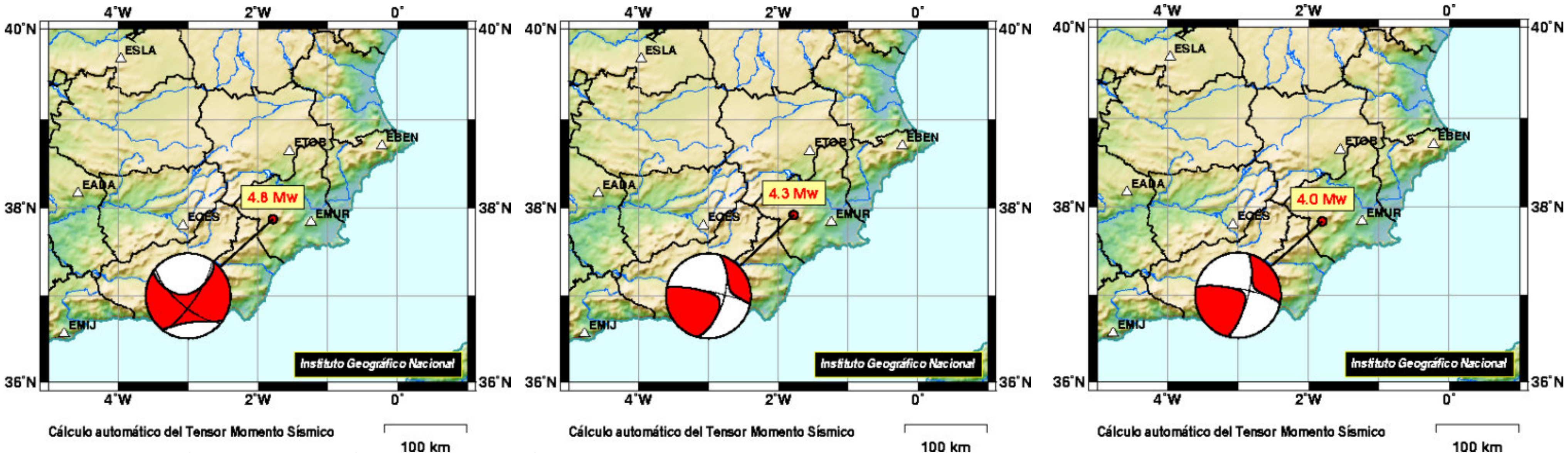
2.1 Seismological Background

The 29th January 2005 earthquake and the following main shocks in the series appear to follow left –lateral strike slip mechanisms on a NNE – SSE trending fault under the Sierra del Cambrón hills.

Of noteworthy interest is a former earthquake in the immediate vicinity on the 8th August 2002 of magnitude 4.8 mbLg (IGN). This earthquake was felt with Imax 6 EMS at the same locations. The legacy of the August 2002 earthquake was still fresh during the current field visits; buildings were damaged again in the same places and rock falls happened from the same cliff faces. In this sense this field report is best be seen in the broader picture of an ongoing earthquake series begun in August 2002.



Epicentral locations and correlations with local geology (Universidad Politécnica de Madrid)



Focal mechanisms for the main events of the current series. (left to right 29/01/2005; 04/02/05; 05/02/05)

2.2 Views and setting

ESE view from location 37.869 N 1.869W (rock face described in 7.1) across the general area

A Sierra del Cambrón Hills

B Possible fault location along the Cambrón Hills from aftershock spread

C La Paca

D seismogeological effects described in 7.1

E Zarcilla

E view from outcrop above town of Zarcilla across the general area

A Sierra del Cambrón Hills

B Possible fault location along the Cambrón Hills from aftershock spread

C La Paca

D Zarcilla

E Cemetery

2.2 Building stock

Most buildings in the macroseismic area are family homes and farmsteads. Up to about the1950s most structures are characterised by load bearing masonry wall constructions of fieldstone set in mortar with wooden floor and roof joists supporting tiled roofs. Since the 1960s new construction is generally Reinforced Concrete (RC) structures with prefabricated RC joists and concrete screeds laid over hollow ceramic tile coffering for floor and roof slabs. Walls are non-load bearing rendered brick infill panels.

Many composite structures exist, with traditional fieldstone coexisting with concrete block masonry units in repairs, additions or extensions. In Modern new-build structures, steel is often used for large spans supported on concrete columns.

A number of industrial installations are present in the area including large concrete silos and cement factories.

2.3 Skill base

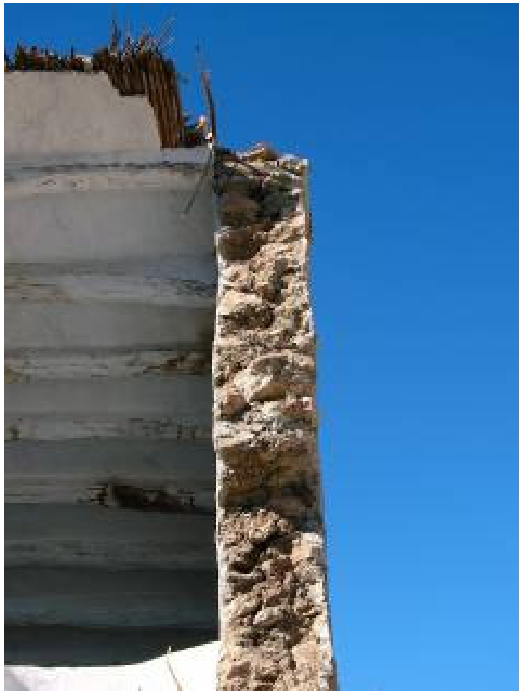
Low construction skills and poor construction practices characterise the performance of local traders who generally perform small-scale jobs like housing or small commercial buildings accompanied by poorly defined architectural projects. Institutional jobs like schools, health centres and upper scale housing appear to benefit from properly engineered solutions with detailed architectural projects and skilled contractors.

2.4 Seismic design considerations

The area is in a zone with base shear of Ac = 0.12g according to the location of the municipality of Lorca in the Spanish seismic resistant building code NSCE-02.

2.5 Seismic design history

Building date (planning application)	Seismic resistant code
> 11/2002	NSCE-02
> 02/1994 < 11/2002	NSCE-94
>1974 < 02/2002	PDS/1 1974



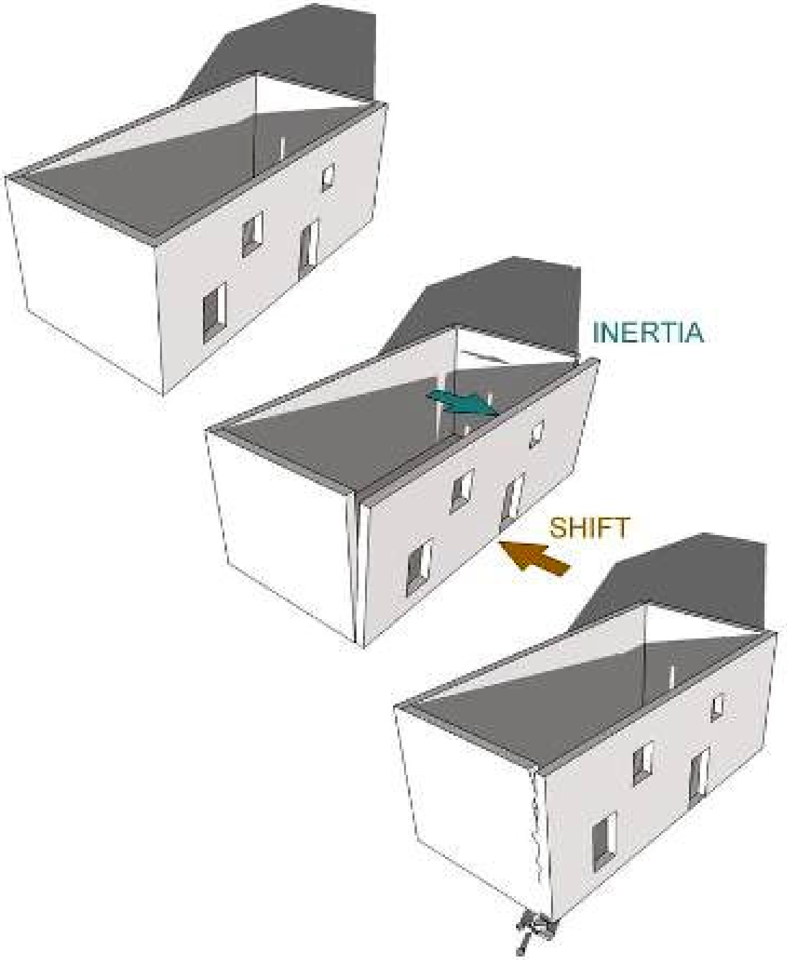
Traditional loadbearing fieldstone masonry exposed in a damaged building. Roof system is roughly formed wooden joists and mortar screed over a bed of canes.

Modern construction systems for a housing project in zarcilla, RC frames.

3 Damage to masonry structures

3.1 Drift of load bearing masonry walls

Drift of load bearing walls is caused by inertial forces acting on heavy massive masonry walls that are inadequately restrained by floor or roof systems or other perpendicular walls. This type of damage is most often observed in fieldstone masonry walls where true connections between walls are difficult to achieve, particularly in an ageing building stock. This type of damage is also present in unskilled modern construction with brick or blockwork walls where walls have not been tied together.



Drift of load bearing masonry façade. Zarcilla (Grade 2 vulnerability A)

Drift of load bearing masonry façade. Zarcilla (Grade 2 vulnerability A)

3.1 Drift of load bearing masonry walls (cont.)

Drift of load bearing masonry in Zarcilla. (Grade 2 vulnerability B)

Drift of bearing walls also affects internal partitioning as in this building in Zarcilla. (Grade 2 vulnerability B)

Slight drift of load bearing masonry in fieldstone construction. El Rincón. Note patched damge of the 2002 earthquake (Grade 1 vulnerability A)

Very slight drift of load bearing masonry in masonry construction. Doña Inés (Grade 1 vulnerability A)

3.1 Drift of masonry walls (cont.)


Heavy Drift of many elements in blockwork construction. La Paca (Grade 3 vulnerability B)


Drift of load bearing masonry in composite construction. La Paca. Note repairs from the 2002 earthquake (Grade 2 vulnerability B)


Drift of walls in blockwork construction. Zarcilla (Grade 2 vulnerability B)


Heavy Drift of walls in blockwork construction. La paca (Grade 3 vulnerability B)


Drift of walls in blockwork construction. Zarcilla (Grade 2 vulnerability B)

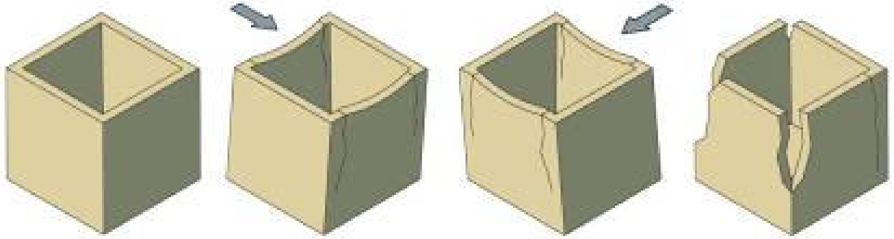
3.2 Corner Failure

Corners in unreinforced masonry construction are very vulnerable to alternating drift and the cyclic reversal of loads, particularly when one wall is stiffer or stronger than the other.

Corner failure in masonry construction in Zarcilla. (Grade 3 vulnerability B)

Detail of building at left

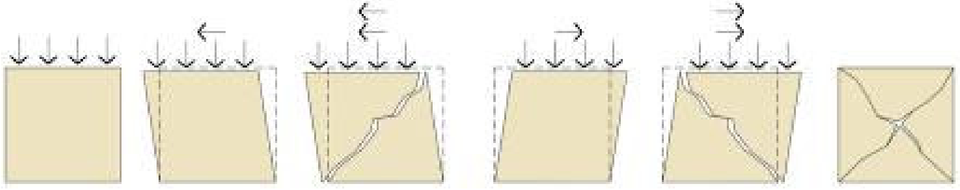
Corner failure. La Paca. (Grade 3 vulnerability A)



Advanced corner failure in Zarcilla. (Grade 4 vulnerability A)

3.3 Shear damage to masonry walls

Walls with insufficient shear strength exhibit diagonal cracking. With cyclic load reversal a characteristic X crack develops.



(left) shear damage in a building in Zarcilla (Grade 2 vulnerability B)

(right) The larger the window openings, the smaller the piers for shear resistance in unreinforced masonry construction, as in this furniture shop in Zarcilla. Inside shear walls are also similarly damaged. (Grade 3 vulnerability B)

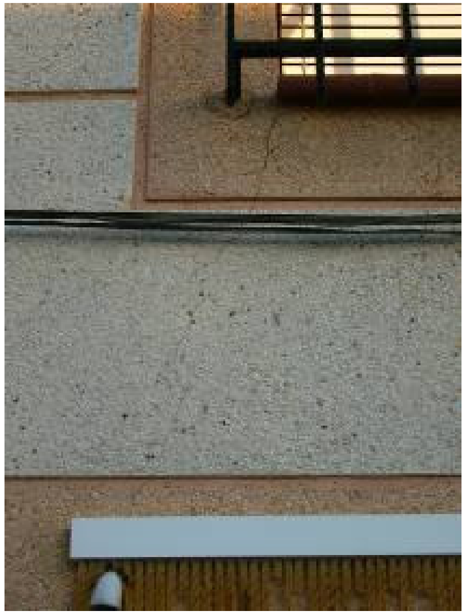
3.3 Shear damage to masonry walls (continued)

This house in Zarcilla suffered extensive shear damage in all walls and especially in vulnerable places like window lintels and corners. There is pounding damage to the column connection at the first floor level and heavy damage to internal partitions. (Grade 3 vulnerability B)

3.3 Shear damage to masonry walls (continued)

The town of Doña Inés, located over a limestone outcrop was only slightly damaged as compared with Zarcilla and La Paca located over quaternary fill, despite a smaller epicentral distance. This type of slight shear damage to walls was typical of damage in this location and assigned an intensity of 5 (Grade 1 vulnerability A)

Another slightly damaged home in Doña Inés (Grade 1 vulnerability B)



3.4 Wall failure (toppling)

Wall toppling from inertia forces in massive masonry is common after damage from drift and loss of connection with other walls. (3.1) Gable, unsupported and unloaded end walls are especially vulnerable to toppling as they are easily pushed out when not tied back to horizontal elements like floors and roofs.

The direction of the roof joists in this house in Zarcilla to the right indicate the failed wall was an unsupported gable wall. Heavy damage has resulted to the roof and other walls from this failure. (Grade 4 vulnerability A)

(Below right) toppling failure in a simple unbraced stone wall.

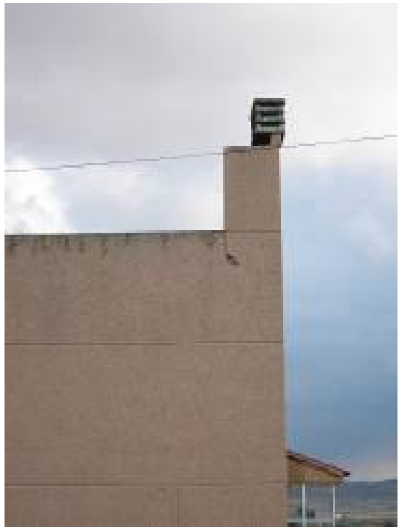
This heavily damaged wall in a vulnerable home in La Paca fell out after loosing connection with an internal perpendicular wall that has also been damaged. (Grade 4 vulnerability A)

3.4 Wall failure gable wall failure (continued)

Gable wall failures from various homes in La Paca and Zarcilla (Grade 3 vulnerability As and Bs)

3.5 Chimneys

Unreinforced chimneys are fragile elements easily damaged by mild shaking.



A missed opportunity. Hours after the earthquake a new unreinforced chimney is built while the remains of the former one litter the road, assuring a similar outcome during the next earthquake.

Damaged chimneys; old and new

3.6 Eaves

Overhanging eaves in traditional construction are heavy and fragile and easily broken off during moderate shaking.

Fallen eaves in homes in La Paca and Zarcilla (grade 2 vulnerability A in all cases)

4 Damage to RC frame buildings

4.1 RC frame members

Minor damage was generally observed by individual members in RC frames. In some situations cracks indicate initial stages of plastic hinging in unfavourable locations like column to slab connections, suggesting inadequate moment resisting frame connections.

A plastic hinge developing in a column head supporting an off-centre steel joist. (Grade 3 vulnerability C)

Small cracks in a RC column in a home in Zarcilla revealed in an inspection. (Grade 2 vulnerability C)

4.2 Shear transfer to non-bearing infill and partitioning walls

X-cracks in masonry infill panels are unequivocal evidence that these non-load bearing walls have been subject to shear stress. In RC frame buildings this may happen when the structural frame lacks rigidity and partition walls are loaded as a result of deformations and displacement of the main structure.

Two conclusions are possible; if displacements are as planned, then specialist architectural detailing must be provided to avoid interaction between structure and infill walls. This is an unreasonable technological demand for economy construction in rural areas.

The other conclusion is that current RC frames are generally lacking in stiffness if they are to be used with brick partitioning, which is an trend firmly implemented in the construction culture of Spain, and must be stiffened up to reduce displacement. This option, along with replacing brittle hollow tile brick units with grouted concrete block units properly tied back to the structure is a reasonable request from moderately skilled contractors and should drastically reduce shear damage to non-bearing elements.

Moderate damage to infill walls in this recently completed home in La Paca. (grade 2 vulnerability C)

4.2 Shear transfer to non-bearing infill and partitioning walls (continued)

Moderate damage to infill walls in this recently completed home in Zarcilla. Note the continued damage done by aftershocks and inspection in the photograph on the right taken a few days later. (grade 3 vulnerability C)

4.2 Shear transfer to non-bearing infill and partitioning walls (continued)

Moderate damage to infill walls in this home in Zarcilla. There appears to be slight damage to the column slab connection in the left hand photograph. (grade 3 vulnerability C)

4.3 Damage to ceilings

Two main ceiling types in the area; suspended plaster or fibre ceilings and plastered surfaces laid directly onto ceiling slabs. With the exception of mechanised suspended systems in engineered buildings like the school at La Paca, brittle plaster ceilings were extensively damaged during the earthquake often falling over corridors, stairs and other vital escape routes. In mechanised systems damage was limited to fall of lighting baffles or lighting units, still posing a hazard.

Damaged ceilings of different types in various buildings in La Paca and Zarcilla

4.4 Roofs

Loose tiles that are not fixed down are easily dislodged at intensities above >6 EMS. A commonly observed damage was that caused by roofs laid over brick spacer walls as in the two lower right photographs; an established practice for roof formation in Spain.

Damaged Roofs in various buildings in La Paca and Zarcilla

4.5 Architectural fittings

Different types of damage to decorative elements, balustrades and facing material in Zarcilla corresponding to damage of grade 2 across different vulnerability types.

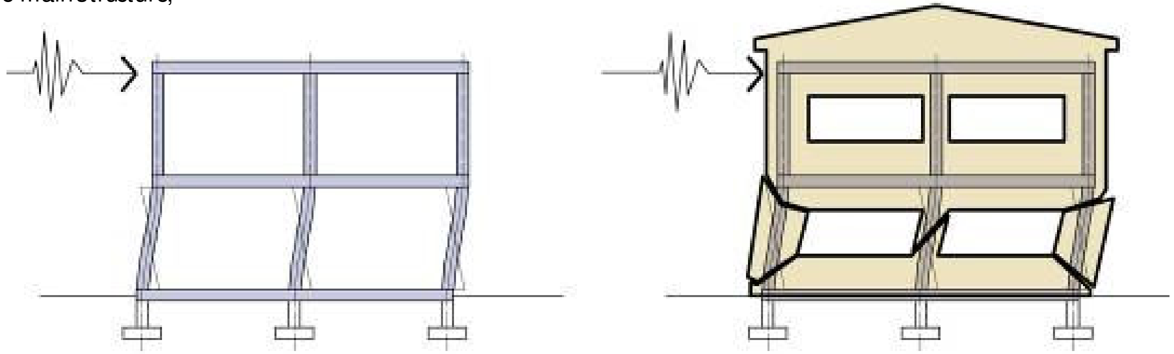
4.6 Case study; Civic centre in La Paca.

2 storey RC building with brick infill panels. (completed 1992) PDS/1 1974 code

This civic centre in La Paca has suffered moderate non-structural damage to partition masonry infill panels. A general survey of the building reveals no horizontal bracing system available other than the slender column connections to the heavy floor slabs. The lack of stiffness of the structure has resulted in large displacements of the ground floor which have been transmitted to the brick infill panels and partitioning walls, shearing them to pieces. Note the soft storey effect, with damage confined to the ground floor where horizontal loads are greatest on account of the heavier mass above and denser partitioning in the upper floor. This building was desperately in need of some stiffness and a concrete lift shaft might have given the structure the necessary shear strength to avoid loading the partition walls, but it was a fragile brick shaft and even that was badly sheared. Despite heavy partition damage there is only minor structural damage with hairline cracking and spalling in column heads signalling the beginning of plastic hinge formation. Despite low structural damage, public confidence in this civic building is shattered and thus a candidate for replacement or major overhauling.

Diagnosis No primary seismic resistant strategy evidenced; lack of structural stiffness, brittle and fragile infill walls, soft story effect. (Damage grade 3 vulnerability C)

X cracks are unequivocal evidence that these curtain walls have been subject to shear by lack of stiffness of the main structure,



4.6 Case study; Civic centre in La Paca. (continued)

External views of the building showing moderate to heavy damage to brittle infill brick walls

4.6 Case study; Civic centre in La Paca. (continued)

Indoor partitions have also been subject to heavy shear forces with conspicious X cracks and partial failure of entire wall sections. Although structural damage appears to be slight, this is an unaccesptable degree of damage for an institutional building.

4.7 Case study; Health Centre in La paca

1 storey RC building with steel truss roof and concrete block infill panels. (unknown completion date)

This health centre in La Paca has a very lightweight steel truss roof over a RC column grid with internal and external walls of concrete blocks. This very unrestrained and unconfined structure with many stand-alone columns shook itself free from the brittle concrete blocks built against and around its structural members. This is a poorly conceived building from the point of view of architectural detailing. All wall contacts with structural members have been damaged. Many partition walls inside show signs of shear damage. Some of the steel roof trusses appear to have shifted from their anchor plates on the column heads. There appears to be no structural damage but there is moderate non-structural damage to most walls including ceilings and indoor fittings. This is unacceptable damage for a medical centre.

Diagnosis Lack of structural stiffness, brittle and fragile infill walls, Inadequate architectural detailing. (damage grade 2 vulnerability C)

This is the wrong type of walling material for the wrong type of structure and detailed in the wrong way.

4.7 Case study; Health Centre in La paca (continued)

Internal walls in this health centre show signs of shear damage with diagonal cracks. Ceramic tiles have been dislodged everywhere and the roof trusses appear to have been shifted from their base plates on the column heads.

4.8 Case study; Private home in Zarcilla

2 storey composite non-engineered structure (steel; RC; masonry) of recent completion date.

Sadly for the affected family, this appallingly conceived house is a non-engineered mish-mash of structural solutions with very poor structural and architectural detailing. Ambitiously cantilevered balconies and roof eaves were executed with no ring beams at the ends of prefabricated RC joists, allowing members to vibrate and wobble freely like individual keys of a piano. Roof joists rested as point loads on the edge of this non code-compliant cantilever which snapped off destroying the first floor cantilever in its way down. This extraordinarily hazardous building type illustrates the risk generated by unskilled construction practices in rural Spain.

Diagnosis Poor structural concept and unskilled architectural detailing. (damage of grade 4 vulnerability B)

External views of the building showing heavy damage to individual roof and balcony elements.

4.9 Case study; School in La Paca

2 storey RC structure with brick infill panels completed 2002 (NCSE-94 code)

This fine building suffered only very minor damage to non-structural elements like spalling of brickwork at expansion joints and the fall of suspended ceiling panels and light fixtures.

Diagnosis Good engineered building with fine architectural detailing. Non-structural damage grade 1 vulnerability D

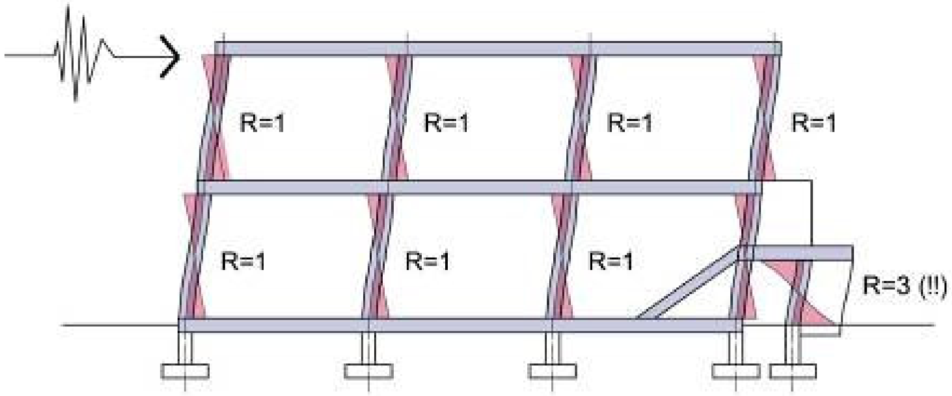
Slight pounding damage between two sides of an expansion joint and slab contact with the brick face. Cosmetic damage to a well built building.

4.10 Case Study; 'Short Column syndrome' in a building in Zarcilla

2 storey RC building with brick infill panels. (under construction) NCSE-02

A 'short column' effect was observed in this RC frame house under construction. Structural elements become loaded for horizontal forces according to their stiffness, and this very stiff stair column (because its short) received a large horizontal force from the rest of the structure because the stair slab was connected to the main structure. An expansion joint between the slab and main building column would have avoided damage.

Diagnosis *Damage to an individual structural element because of an inadequate structural concept. Damage grade 3 vulnerability D*



Memebers attract horizontal loading according to their stiffness. Because the stair slab was connected to the main structure, the small stiff stair column recieved horizontal loading from the whole structure.

Short column location under a stair slab that is connected to the main structure; poor rebar splicing detailing is also visible, probably contributing to the column failure in this location.

5 Effects on objects and furnishings.

5.1 Household goods

In La Paca small objects were thrown down from shelves and tables in many households. Pictures were thrown down from walls, lamps overturned, some glassware and crockery broken and a few instances were reported of TV sets being toppled over or thrown down.

In Zarcilla, these effects appear to have been generalised in all households. Heavier items like hardback volumes were thrown down from bookcases, more instances of fallen TV sets were observed, and in some households cabinet doors were thrown open and the contents spilled out, including at least one fridge that spilt perishable goods onto the floor. Many objects like bottles and cans were thrown down from supermarket shelves as well as overturning bottles originally placed on the floor, filling supermarket aisles with fallen produce. No falls were reported from genuinely heavy and stable objects like cash register machines in supermarkets or microwaves in households, which limits the maximum intensity range.

Fallen produce from another supermaket in the area.
La Verdad de Murcia

3 views of fallen produce from shelves in a supermarket in Zarcilla indicating an intensity of at least 6 and resembles 7; *Objects fall from shelves in large numbers*

5.1 Household goods (continued)

3 pictures from a second floor in a home in Zarcilla; drawers and cabinets were thrown open and contents spilled onto the floor including contents from the fridge. Note the damaged TV set in the kitchen which was also thrown down. Heavy books were knocked down from the bookcase in the living room suggesting an intensity of at leas 6 or more.

5.1 Household goods (continued)

3 pictures from a second floor living room in a home in Zarcilla; Objects and glassware were thrown down and broken including the TV set. Some glassware that was not thrown down was broken by impacting each other or the cabinet formwork. Heavy fall of ceiling plaster.

5.2 Furniture

Ordinary household furniture like tables, chests of drawers and chairs were shifted between 5 and 10cms. A few instances of toppled furniture were reported, including a top-heavy cabinet and heavily laden steel assembly shelving systems.

Toppled overloaded steel assembly racks in a hardware shop. Overturning of top heavy furniture is first used as a diagnosis for intensity 7. *La Verdad de Murcia*

Toppled top-heavy furniture. *La Verdad de Murcia*

Fallen and damaged television set in a home in La Paca

Light furniture was shifted >10cms in this home in Zarcilla

5.3 Cemeteries

In both the cemeteries of these towns votive figures, statues and flower jars were overturned, including those confined behind the glass frontages of grave niches. Some marble inscription slabs were dislodged and broken.

The cemetery of Zarcilla a few kms SW from the town

Vases and statues thrown down from an altar

Damage to a crypt building

Votive objects thrown down behind glass in a niche

Votive objects thrown down behind glass in a niche

5.3 Cemeteries (continued)

Damage to gravestones in Zarcilla

Damage to gravestones in Zarcilla

Damage to niche structures in Zarcilla

6 Mechanical installations

6.1 Water tanks.

Unrestrained tanks are vulnerable because of the dynamic action of sloshing water. In some households unrestrained water tanks were shifted, toppled or overturned.

Overturning of a water tank in Zarcilla.

Toppling of a water tank in Zarcilla. Note shear damage to wall suggesting grade 2

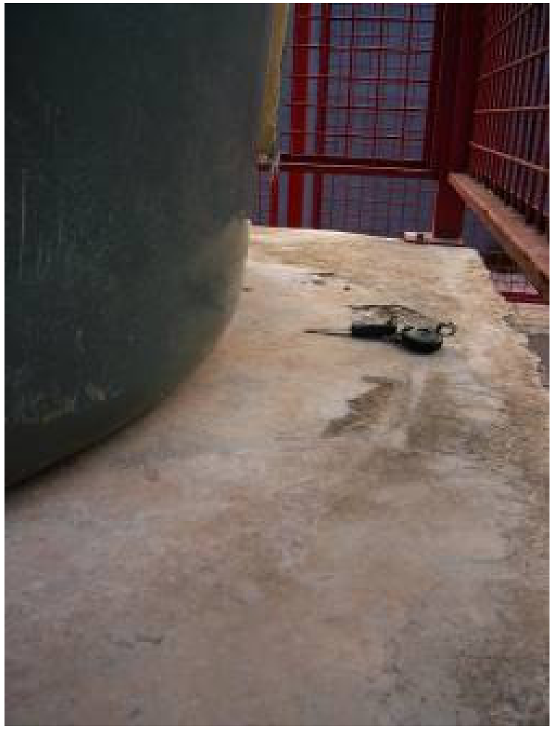
This water tank in La Paca was shifted, bending the plumbing connection and damaging the pedestal

6.2 La Paca civic centre water tank.

In this building a 1.2m diameter X 1.6m high fibre-glass water tank (about 1500L) set upon a 1m high RC pedestal on ground was shifted >10cms and punctured by the plumbing connection which was bent backwards. The tank was also ripped open by what appears to be stress caused by sloshing water.

Bent and punctured connection, suggesting the tanks was violently displaced in this direction.

The side was burst open, resembling the ‘elephant foot’ damage observed in larger steel silos by sloshing water in major earthquakes



Marks on the concrete pedestal leave a tell-tale story of the tank’s displacement

7 Seismogeological effects (2002 and 2005 events)

7.1 Rock falls

Two rock fall sites were initiated by the August 2002 earthquake. Fresh rock falls from the current shocks are hard to distinguish from the earlier event but appear to be less voluminous as unstable faces were already shaken off in 2002. The well weathered limestone rock faces appear to have been in a state of precarious balance before the 2002 event suggesting high intensities >6 had not been recorded locally for some time.

2 Rock fall sites in the hills between La Paca and Zarcilla.

Rock fall site **A** from the 2002 earthquake. Main boulder is circa 25m3

25m3 boulder from rock fall site A

7.1 Rock falls (continued)

Rock fall on the Lorca – Caravaca road

Rock fall on an old quarry face, Zarcilla

Rock fall site **B** from the 2002 earthquake. Main boulder is circa 10m3

7.2 Cracks

Fine cracking <5mm was observed on asphalt road surfaces at various locations

Carcking in streets of La Paca (left) and Zarcilla (right)

8 Social effects

8.1 Effects on people

Most people reported rushing out of buildings or dashing for their children or loved ones. The owner of the building discussed in 4.5 exhibited extraordinary nerve wrapping her child around a duvet to protect it from falling ceiling material. Generally speaking streets were filled with panicked and excited people. An observer in a first floor reported loosing balance and being flung around by the earthquake while an observer in the ground floor supermarket illustrated in 5.1 stated no difficulty in maintaining balance or standing up while objects fell from shelves.

8.2 Injuries

An unconfirmed number of about 6 people received treatment after the earthquake for injuries resulting from falling ceilings and being knocked by furniture. The early Saturday morning event was well timed in favour of good fortune as most people were indoors and protected from the rubble of eaves, chimneys and gable walls that fell into empty streets.

8.3 Psychological stress

Psychological stress resulted from the protracted swarm series and recurring secondary events, in particular after the secondary earthquake on the 3rd of February followed by about 50 perceptible events during that day and following night. The author and other accompanying engineers were able to feel and report macroseismic observations both indoors and outdoors for a number of shocks between the 4th and 6th February with mb magnitudes ranging between 1.9 and 3.0 and EMS values between 2 and 4. During the night of 3rd February, many neighbours slept in tents or municipal shelters from fear of continued aftershocks. Others sought accommodation with family or friends in neighbouring cities or towns away from the epicentral area.

Frightened neighbours in the streets after the mainshock. *La Verdad de Murcia*

9 Brief Emergency Response

9.1 Protección Civil

Emergency response was coordinated through the Spanish disaster authority *Protección Civil*. The reduced size of the mezoseismal area was a clear advantage and rubble removal and cleaning up was complete 24 hours after the earthquake.

9.2 Shelters

Canvas shelters and marquees were erected for use of families with buildings declared unsafe. Many neighbours with minor damage however chose to use the shelters for fear of aftershocks.

9.3 Prefabricated homes

Work is currently in progress (14.2.2005) for a prefabricated home park in Zarcilla for families declared homeless.

9.4 Financial Aid

3.5M€ has been made available by Spanish authorities for uninsured losses, recovery and reconstruction.

Removing rubble the day after the earthquake. Zarcilla

Temporary canvas shelter in the town square of Zarcilla

Damaged by the earthquake (left) but finished off by *Protección Civil* (right) a day after the earthquake, shows the importance of a quick site visit for accurate observations.

10 Discussion

10.1 Masonry Construction; items for continued discussion:

- Masonry town houses are a diminishing heritage in Spain due to neglect, changing society values, damage from earthquakes and a lack of artisan upkeep.
- Unskilled labour and artisan construction are not the same thing. Artisans are being replaced by sloppy unskilled labour.
- Widespread use of unreinforced masonry units in modern masonry construction by unskilled labour is in evidence.
- Widespread neglect and ignorance of building codes and good building practices by unskilled labour is in evidence.

10.2 Reinforced Concrete Construction; items for continued discussion:

- There is too much damage to non-structural elements in current building practices.
- There is no evidence of bracing elements or shear walls or other primary horizontal loading resistant devices in current RC construction in moderately engineered structures in Spain. Why? because seismic resistance is still not a consideration in the concept phase of projects. Architects are delegating seismic responsibilities to engineers at a late phase when basic arrangements are already committed on plan.
- Moment resistant frames are the only possible seismic resistant solutions available if shear walls and bracing are not used. MRFs are somewhat incompatible with brittle fragile partitioning walls.
- Current construction in Spain is Moment Resistant frames with brittle fragile partitioning walls which explains the widespread non-structural damage experienced in moderate earthquakes in Spain.

Hours after the earthquake a homeowner embarks in self-reconstruction using sub standard materials and poor technical knowledge. There is probably no planning permission for this hazardous job which will be surely damaged in the future.