

# Speedup of post earthquake community recovery: the case of precast industrial buildings after the Emilia 2012 earthquake

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**Abstract** The Emilia, May–July 2012, earthquake hit a highly industrialized area, where some tens thousands industrial buildings, mainly single storey precast structures, are located. Due to the likelihood of strong after shocks and the high vulnerability of these structures, the authorities first asked for a generalized seismic retrofit after the strong shakings of May 20th. In order to accelerate community recovery, this requirement was later loosened, leaving out the buildings which had undergone a *strong enough* shaking without any damage; the *strong enough* shaking was defined with reference to the ultimate limit state design earthquake. To the authors' knowledge, it is the first time that the information on the earthquake intensity and structural damage is used for such a large scale post earthquake simplified safety assessment. In short, the earthquake was used as large experimental test. This paper shows the details of the models and computations made to identify the industrial buildings which have been considered *earthquake tested* and therefore not compelled to mandatory seismic retrofit. Since earthquake indirect (e.g. due to economic halt) costs may be as large the direct ones, or even larger, it is believed that this method may considerably lower the earthquake total costs and speed up the social and economic recovery of a community.

**Keywords** Industrial buildings · Structural safety · Emilia earthquake ·  
Community recovery · Shakemap

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## 1 Introduction

In May to July 2012 several seismic events hit the region of Emilia, in Northern Italy; the main shocks were recorded on May 20th ( $M_I = 5.9$  and  $M_w = 5.86$ ), and on May 29th ( $M_I = 5.9$  and  $M_w = 5.66$ ); significant aftershocks continued until July.

These events caused 27 casualties, and produced heavy damage, mainly to the historic cultural heritage and to the industrial buildings. Several historical building structures collapsed, and some thousands industrial structures, mainly precast one storey reinforced concrete, were severely damaged; [Decanini et al. \(2012\)](#) made a timely and comprehensive review. The largest part of the industrial structures was in fact designed to carry only gravity and wind loads, coherently with the structural code at the moment of design.

These structures, from the seismic point-of-view, had clear structural deficiencies, particularly in the beam-column and beam-roof connections. Due to this poor detailing, several collapses occurred during the second event in structures that had already been damaged during the first event. However collapses were observed also for structures in which no damage had occurred during the first event.

Another worth-of-notice feature is the shift of the epicenter of the May 29th event from the epicenter of the May 20th event. Such aspects were observed also in the 1997 Umbria-Marche earthquake sequence, and, although less pronounced, in the 1976 Friuli event.

In Italy, basing on the experience gained from past earthquakes (Irpinia '80, Abruzzo '84, Basilicata '90, Reggio Emilia '96), methods to estimate post-earthquake structural safety are routinely used and updated. These methods are based on structural typology and observed damages, as reported from an expert surveyor (engineer). These rapid assessment methods, detailed by [Baggio et al. \(2000\)](#), aim at identifying buildings unsafe for immediate occupancy, and at assisting about further checks and retrofit measures. Although these procedures proved effective during recent earthquakes, they lack accuracy, mainly because of the surveyor subjective judgement and also for the uncertainty on the local earthquake intensity. These aspects have been quite significant for the Emilia event, also for the characteristics of the structures stock.

Disaster management authorities had to cope with the high damage observed in industrial structures, the uncertainties on the information gained from the surveys, public safety, necessity of a rapid recovery of activities with the least possible impact on social and economic life.

Two main regulations were issued, the first one on June 6th, by the [Italian Government \(2012\)](#), the second one on August 1st by the Italian Chambers ([2012](#)); both concerned only the region struck by the earthquakes (part of the Emilia Romagna region, plus small parts of the confining regions of Lombardy and Veneto).

The first, June, regulation was issued a few days after the second major event of May 29th, and aimed at rapid socio-economic recovery, in the short term, and a higher generalized safety level, in the medium term (6 months). Within six months, in fact, all industrial structures had to be verified and retrofitted with the provisions of the current Italian structural code ([Ministero delle Infrastrutture 2008](#)), namely using chapter 8, *existing structures*. The seismic verification earthquake was lower with respect to the one used for new structures; this lower level was subjectively set at 0.6 times the seismic load for the design of new structures.

The short term checks entitled to a temporary occupability permission: if no evidence of heavy structural deficiencies were found, or if they were solved for, the structure could be normally used, although for a maximum of six months. The checks on structural deficiencies were minimal, in order to make them simple and timely.

If either:

- i. no connections between vertical and horizontal structural elements, or between horizontal elements was found;
- ii. pre-cast infill elements were not adequately connected to the structure;
- iii. shelf systems (carrying heavy materials whose collapse may result in damage or collapse of the structure) were unbraced;

the deficiencies had to be solved for before using, even temporarily, the structure.

i., ii. and iii. are in fact the most frequent causes of seismic collapse; clearly they do not cover all possible vulnerabilities. The short term provision tried in fact to compromise between timely recovery and safety, accepting a lower level in the short term.

The provisions in the longer term (verify or retrofit at 60% the seismic load for new structures) were however incoherent with the safety level accepted elsewhere in Italy. In fact, existing structures, designed with older structural codes and often not satisfying the requirements of new ones, are compelled to upgrading at the newer code requirements only if there is load or usage change; in all other cases, the usage of the structure can continue unchanged.

What appears a compromise between the initial requirement of June 6th ([Italian Government 2012](#)): within six months industrial structures in Emilia had to be retrofitted with the provisions of the current Italian structural code ([Ministero delle Infrastrutture 2008](#)) and what was customarily accepted elsewhere in Italy (and generally in all countries) was found within the second regulation by the Italian Chambers ([2012](#)).

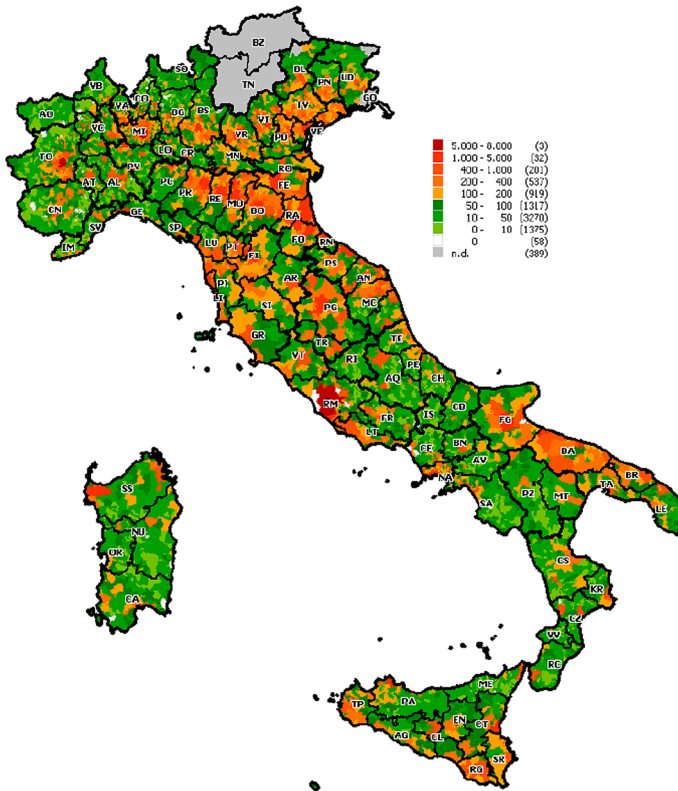
This one, in short, made use of the recorded earthquakes as a test: if the industrial building had undergone a *strong enough* earthquake without any damage, both for the structural and non structural and installations parts, this information was used as a test to prove (or disprove) acceptability of the structural safety level. Since the first regulation ([Italian Government 2012](#)) set the seismic load with which to verify (and retrofit, if the verifications were not satisfied) the structures at 0.6 times the seismic load (defined via the elastic response spectrum) for new structures, the *strong enough* earthquakes were similarly defined. More precisely, if the local elastic earthquake response spectrum was higher than 0.7 times the design response spectrum, and the structure had well performed, then the regulation by the Italian Chambers ([2012](#)) stated there was no obligation to verify (and possibly retrofit) with 0.6 times the seismic load for new structures. Good performance was conservatively defined as a stress and deformation state with the linear elastic field, both for the structural, non structural and installations building components. A further requirement was contained, since the local response spectra had to be estimated via the *shakemap* model of [Wald et al. \(1999\)](#), adapted for the case of Italy by the Italian Istituto Nazionale di Geofisica e Vulcanologia (INGV) as detailed by [Ministero delle Infrastrutture \(2008\)](#) and published on the internet ([INGV 2012](#)).

In the following sections, the procedure used to compute the local earthquake spectra will be illustrated. One of the procedure goals was simplicity of the final results, since some tens thousands industrial structures were concerned with its direct use.

### 1.1 Industrial buildings in Emilia

Industry is a very important activity in Emilia; some figures may help appreciate the social and economical importance of industry and industrial buildings.

The Emilia Romagna region is one of the most industrialized regions in Europe: 34% of working population are employed in industry, with 25% of gross income dependent on industrial production as reported by [ISTAT \(2012\)](#). In Italy about 655'000 buildings are



**Fig. 1** Density of industrial buildings in Italy

classified industrial by the [Agenzia del Territorio \(2012\)](#); 60 % of these are located in the northern part of Italy, with the remaining 40 % equally spread between southern and central Italy. Figure 1, excerpted from [Agenzia del Territorio \(2012\)](#), shows their density. The largest number is around the major towns, and, unfortunately, within the area struck by the May–July 2012 Emilia earthquake.

In Emilia Romagna about 80'000 (12 % of the total for Italy) industrial buildings are present ([Agenzia del Territorio 2012](#)), one third of them being warehouses. The most frequent typology is reinforced concrete (85 % of the total), more than two thirds of the pre-cast type. With reference to 2012 prices, structural construction costs are estimated, on average, 100€/m<sup>2</sup>; the market value is equal to about 600€/m<sup>2</sup>. Market value is estimated by the Italian governmental body Agenzia del Territorio, within its 2012 report ([Agenzia del Territorio 2012](#), Rapporto immobiliare 2012). It is the mean value of samples excerpted by official (registered sale contracts) and non official (estimations of local officials) data.

## 2 Procedure to estimate the local response spectrum

Industrial structures in Emilia are central to economic, and therefore social, activity and fast community recovery. On the other hand, they are seismically fragile, and could have been subjected to the further strong earthquakes which were expected in Emilia. This issue was

complex to solve. The simple criterion contained within the August 1st, 2012, law, issued by the Italian Chambers (2012), allowed to deal with a difficult issue, through a rational, though subjectively calibrated, rule.

The procedure to define the part of the territory where the earthquake elastic spectrum had been higher than 70% the design spectrum is composed of the following steps:

- I. definition of the spectral acceleration shakemap for a particular event. The shakemap for the  $i$ -th event, at the site with longitude  $lon$ , latitude  $lat$ , for the natural period  $T$ , is indicated with  $S_{e_i}^*(lon, lat, T)$ . 5% damping is assumed. Further details are given in the following section.
- II. definition of the maximum shakemap, among the different events that have hit the region, i.e.  $S_e^*(lon, lat, T) = \max_i \{ S_{e_i}^*(lon, lat, T) \}$ ;
- III. comparison of the maximum shakemap  $S_e^*(lon, lat, T)$  with  $S_e(lon, lat, T)$ , the code design spectrum for new structures; 5% damping is assumed for both experimental and design spectra.
- IV. determination of the areas where  $S_e^*(lon, lat, T) > 0.7 * S_e(lon, lat, T)$ . The areas are defined as the union of the points  $(lon, lat)$  where the inequality is satisfied. These areas are defined *exclusion zones*, with reference to exclusion from obligation, in case of good structural performance, of structural verification.

The 0.7 threshold, together with the requirement of linear elastic behavior, implies, for ductile mechanisms, a behavior factor lower than 1.5, compatible with these structures.

The design acceleration spectrum,  $S_e(lon, lat, T)$ , is defined by the Italian structural code (Ministero delle Infrastrutture 2008) via the values, tabled for each point on the Italian territory on a  $1 \text{ km} \times 1 \text{ km}$  grid, of  $a_g$ ,  $F_o$ ,  $T_C^*$ . These are, respectively, the maxima of the expected ground acceleration on bedrock, spectral amplification, and a parameter defining the spectral shape. *Shake maps* The shake maps provide a measure of the shaking intensity at the ground surface for a region hit by an event. These maps are essentially based on seismological instrumental data and are obtained by interpolating among the different sampling points. The Italian procedure is developed by the Istituto Nazionale di Geofisica e Vulcanologia, INGV, and is specialized, departing from the United States Geological Service, USGS, procedure described by Wald et al. (1999), to the Italian territory. The tool is used for emergency management operations carried out by the Civil Protection Department.

The shakemap model uses the two dimensional horizontal earthquake acceleration time histories, recorded at available stations; 5% damping elastic response spectra are computed; data from the recording stations are extrapolated via regional attenuation laws to the whole area under study; maps of iso spectral accelerations (one for each natural period) are finally produced. The model is implemented in a computer software which generates and publishes the maps on the internet almost in real time. Local site conditions are taken into account, via amplification factors based on the shear value velocity averaged on 30 m,  $V_{s,30}$ . Further details are in Wald et al. (1999) and Michelini et al. (2008).

A detailed discussion of the shakemap model, software and of its accuracy is beyond the scope of this work. However the authors devoted time and effort in order to assess the reliability of the Italian shakemap data; the findings are contained in a companion paper which is being published and whose draft is available in Morelli et al. (2013).

The vertical earthquake component has been disregarded within this analysis. In fact, preliminary checks about its influence on the main observed industrial structures failure modes, i.e. unseating of roof tiles or beams, suggested it was not very influential.

The maximum vertical design spectral acceleration in Emilia is, according to NTC08 (mettere riferimento), equal to about 0.16 g. At the expected first period of vibration (1 s.), the

**Table 1** Shake maps parameters for the May 29, 2012 Emilia earthquake event

Longitude	Latitude	pga (%g)	psa (T=0.3 s) (%g)	psa (T=1 s) (%g)	psa (T=3 s) (%g)	Vs30 (m/s)
11.1613	44.8723	37.15	105.24	71.09	7.82	230
11.1613	44.8807	37.14	105.2	71.04	7.82	230
11.1613	44.889	37.1	105.05	70.9	7.81	230
11.1697	44.8807	37.1	104.83	70.75	7.78	230

horizontal design spectral acceleration is equal to about 0.28 g. Therefore, a very conservative estimation for the demand static friction is 0.33, i.e.  $0.28/(1 - 0.16)$ . This value is far below the static concrete—concrete friction coefficient, but is in the range of literature data for rubber-concrete and steel-concrete friction, and helps to explain why some unseating failure modes were observed.

In any case, since the unseating failure mode had to be solved before re-starting to use the industrial structure, as required by the June 6th, 2012, Italian government regulation (see Sect. 1 of this paper), the vertical earthquake component was considered disregarding and has been, for simplicity, not considered within this analysis.

### 3 Application of the method to the Emilia earthquake

For each point on the  $1\text{ km} \times 1\text{ km}$  grid within Emilia, INGV (2012) publishes different earthquake intensity parameters. Table 1 shows a sample of the available data. Each row contains the data for a point specified via its geographical coordinates; each column the intensity parameter. An estimation of the local shear wave velocity is also given, based on large scale geological data. Further intensity parameters, not shown here, are available, including peak ground velocity, an estimation of the modified Mercalli intensity and of the earthquake intensity estimation error.

These data are defined on a grid with half a prime spacing in longitude and latitude; this amounts to about 900 m grid spacing in north—south direction, and  $900\text{ m} \cdot \cos(lat)$  in east—west direction, *lat* being the latitude.

Figure 2 shows the peak ground acceleration shakemaps of the May 20th and 29th, 2012 events. The blue and red triangles within Fig. 2 show the locations of the recording instruments (three dimensional digital accelerometers).

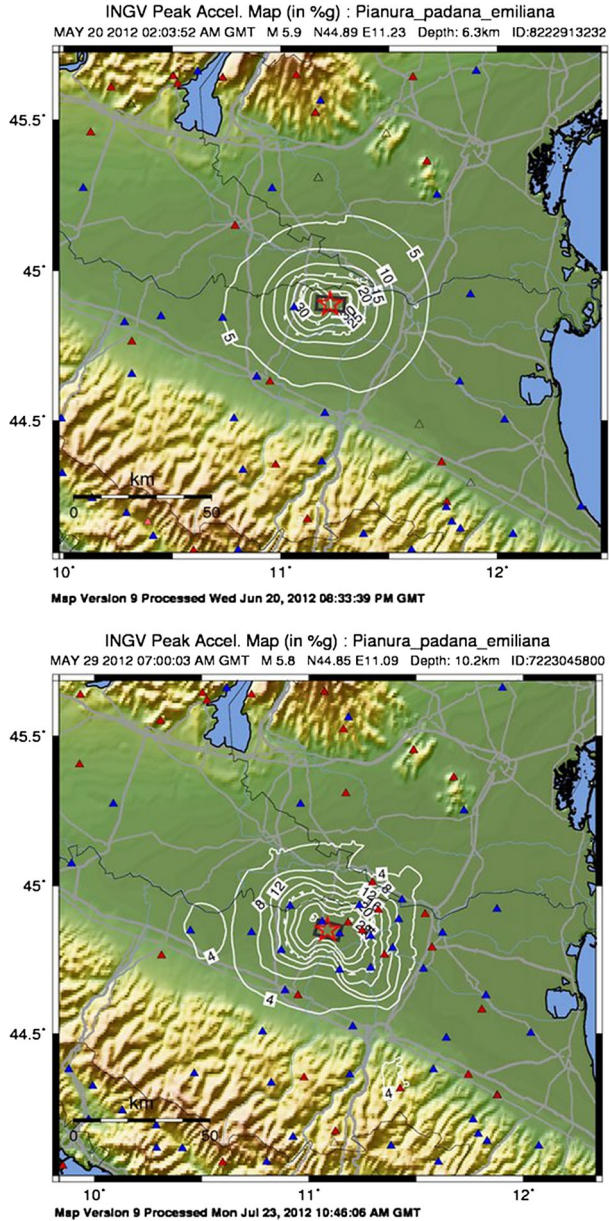
As anticipated in the previous section, a companion paper (Morelli et al. 2013) deals solely with the shakemap model and its accuracy; however some comments on Fig. 2 are expedient. The curves of iso-accelerations are obtained via attenuation of the intensity measured at the accelerometers location. The attenuation laws are regionally calibrated (Michellini et al. 2008), based on past events, in order to compute the local intensity at each point on the territory. If the attenuation laws are circular (i.e. dependent only on distance from the recording instrument), the sub-soil is homogeneous, and few recording instruments are available, as is the case for the first event of May 20th, 2012 (Fig. 3, top) iso-acceleration curves are almost circular.

This is observed also for the 1 second spectral acceleration shakemaps, Fig. 3: the shakemap of May 20th (top of Fig. 3) are close to ellipses.

A large part of the Italian precast industrial buildings has structural behavior that can be assimilated to a simple cantilever. The cantilever (columns) length varies between 5 and 10 m; with the typical permanent loads, the period of the first vibration mode is equal to about

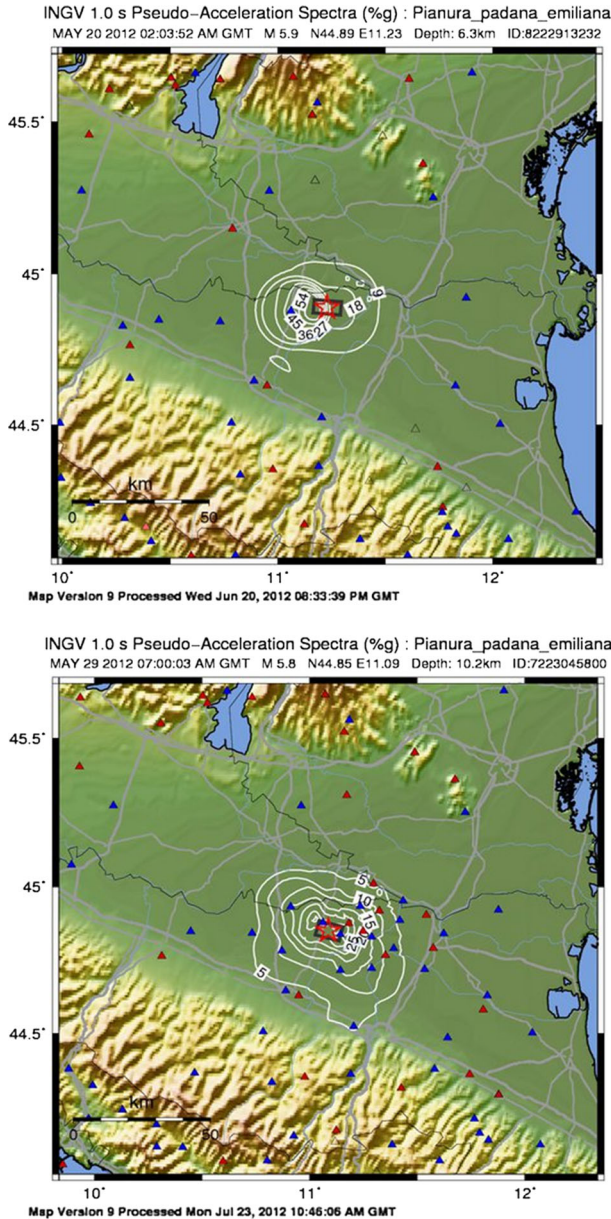


**Fig. 2** Peak ground acceleration shakemaps of the May 20th (*top*) and 29th (*bottom*), 2012, Emilia earthquake sequence



1 s The 1 s value is therefore important for industrial pre-cast structures. However, the INGV shakemaps are given for four periods of the response spectrum: 0, 0.3, 1, 3 s.

After the first main shock, more instruments were spread on the Emilia territory, and the May 29th event iso-acceleration curves (Figs. 2 and 3, bottom) are less regular. This means that they are capable of higher territorial detailing. It should be noted that, despite its approximation, the INGV data were the only available quantitative source of information on the events.



**Fig. 3** 1 s spectral acceleration shakemaps of the May 20th (top) and 29th (bottom), 2012, Emilia earthquake sequence

Once the local acceleration spectra  $S_{e_i}^*(lon, lat, T)$  are defined (step *i.* of the procedure outlined in Sect. 2), step *ii.* requires determination of the maximum, among events, local spectrum, i.e.  $S_e^*(lon, lat, T) = \max_i \{S_{e_i}^*(lon, lat, T)\}$ .

Since tens of events were recorded in the Emilia sequence, a preparatory substep is individuation of those capable of affecting the maximum local response. To this end, a rectangular part of the territory in Emilia was first chosen. The rectangle is the one limiting the municipi-



**Table 2** Events within the Emilia sequence with magnitude higher than 5.0

Date and time (UTC)	Latitude (°)	Longitude (°)	Depth (km)	Magnitude	<i>i</i>
2012-05-20 02:03:52.000	44'889	11'228	6.3	5.9	7
2012-05-29 07:00:03.000	44'851	11'086	10.2	5.8	6
2012-05-29 10:55:57.000	44'888	11'008	6.8	5.3	5
2012-05-29 11:00:25.000	44'879	10'947	5.4	5.2	4
2012-06-03 19:20:43.000	44'899	10'943	9.2	5.1	3
2012-05-20 13:18:02.000	44'831	11'490	4.7	5.1	2
2012-05-20 02:07:31.000	44'863	11'370	5.0	5.1	1

palties affected by the Emilia earthquake, more precisely the municipalities whose seismic retrofitting is affected by the regulations of the [Italian Government \(2012\)](#) and [Chambers \(2012\)](#). The municipalities and the rectangular part of the territory are shown in [Fig. 6](#), and the limiting coordinates are  $10.82^\circ$ ,  $11.9^\circ$  (longitude, east of Greenwich) and  $44.58^\circ$ ,  $44.96^\circ$  (latitude, northern hemisphere).

Now, let  $I$  the number of events with magnitude higher than 5.0 within the Emilia sequence, ordered by increasing magnitude, and  $i$  an index varying from 1 to  $I$ . The events are shown in [Table 2](#).

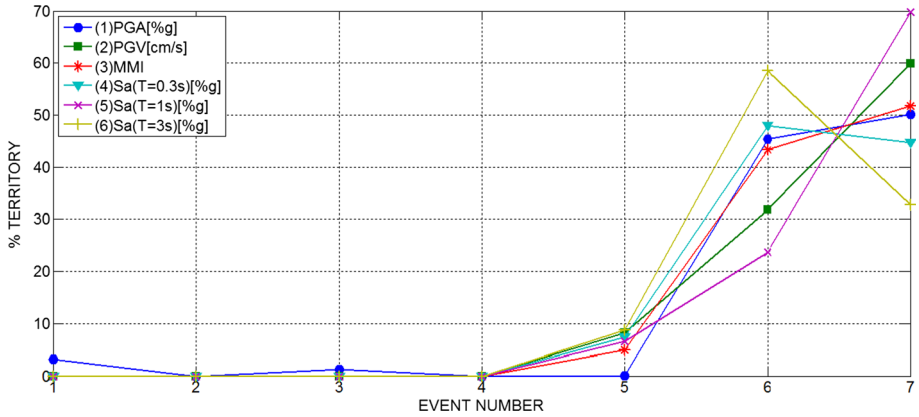
Let  $J$  the number of points on the half a prime grid, defined within the limiting rectangle, and the  $j$  an index varying from 1 to  $J$ . Finally let  $K$  the total number of local earthquake intensity measures, and  $k$  an index varying from 1 to  $K$ . All six available local earthquake intensity measures  $IM$  as given by the [INGV \(2012\)](#) are here considered, i.e. peak ground velocity ( $pgv$ ), modified Mercalli intensity ( $mmi$ ), and four spectral acceleration at different periods (peak ground acceleration,  $pga$ , spectral values at 0.3, 1.0, 3.0 s).

For each of the  $K$  local intensity measures, the  $i$ -th event will have caused the maximum  $IM_k$  at  $j^*$  points, out of the total  $J$  points, i.e. on the  $j^*/J$  part of the territory. Let  $R_{ki} = j^*/J$ , this ratio. The plot of  $R_{ki}$  is shown in [Fig. 4](#). Event number  $i$  is shown on the x-axis; the six intensity measures are different curves;  $R_{ki}$  is on the y-axis. [Figure 4](#) shows that, independently on the preferred intensity measure, the highest two events (magnitude 5.8 and 5.9) cause maximum local earthquake intensity on about 90 % of the territory; the third largest one (magnitude 5.3) and the lower magnitude ones cause the maximum intensity on about 10 % of the remaining territory.

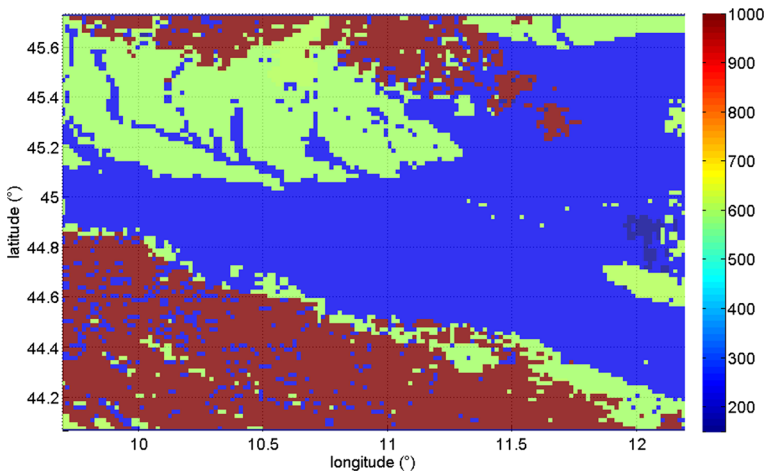
The procedure used by [INGV \(Michellini et al. 2008\)](#) to derive the shake maps makes use of attenuation curves calibrated for bedrock. The actual soil profile at a particular location is taken into account via local amplification factors, which depend on both shear wave velocity  $V_{s30}$  and local earthquake intensity. A discussion of this aspect is within the companion paper of [Morelli et al. \(2013\)](#). Here it is worth noticing that the subsoil within the investigated area is homogeneously classified as C type, according to the Italian code classification ([Ministero delle Infrastrutture \(2008\)](#)), i.e.  $V_{s30}$  within the [180; 360 m/s] range. The shear wave velocity  $V_{s30}$ , assumed by [INGV \(2012\)](#), is shown in [Fig. 5](#).

The 1 s spectral acceleration shakemap,  $S_e^*(lon, lat, T = 1s)$  is depicted in [Fig. 6](#). The iso-acceleration curves are computed with a linear interpolation between grid points.

The third step requires the identification of the part of the Emilia territory where the spectral acceleration, as defined by the [INGV shakemaps](#), has exceeded 0.7 times the design spectral acceleration.



**Fig. 4** Percent of territory in which the maximum value of the parameter is governed by the *i*-th event



**Fig. 5**  $V_{S,30}$  shear wave velocity (m/s)

This definition would imply verification at the periods of vibration of the significant modes, at least three modes, and would thus result in a significant complication. Further, it should be noticed that the INGV shakemaps are published only at four periods: 0, 0.3, 1.0 and 3.0 s

It has been first checked whether the four spectral accelerations matched any of the ultimate limit state design response spectra, as defined by the Italian code (Ministero delle Infrastrutture 2008) for different soil types. The result, discussed later in this section, has been that the shape of the 475 years return period, soil type C, design spectrum, matched the earthquake acceleration spectral shapes best, as compared to other soil types.

The 475 years return period, on C soil type, has then been retained as the reference functional form. Notice that, since according to the Italian code (Ministero delle Infrastrutture (2008)) the design spectrum parameters change continuously on the territory, thus does the reference functional form.

Now, at each point on the territory, and for each event, four samples ( $T = 0.0, 0.3, 1.0, 3.0$ s) of the *i*-th event spectrum are available, together with the reference functional form.

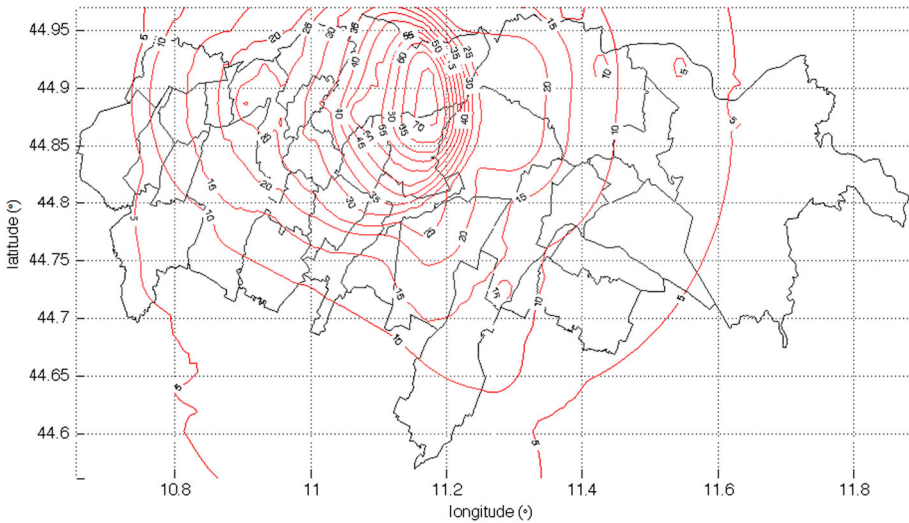


Fig. 6 Maximum spectral acceleration for  $T = 1$  s and for all the events (%g)

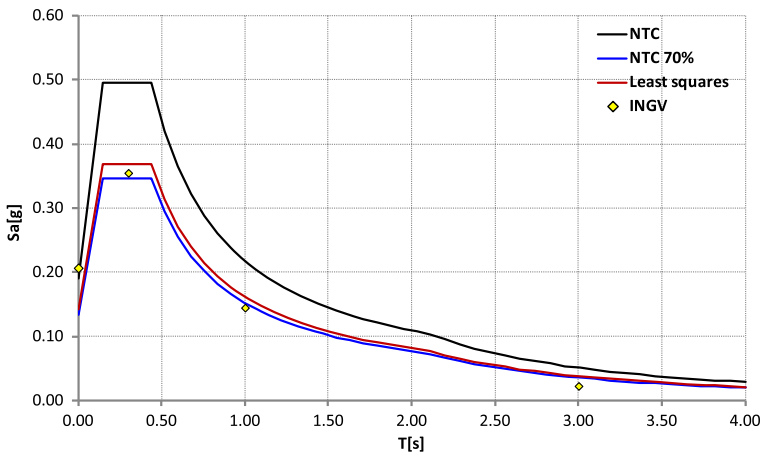
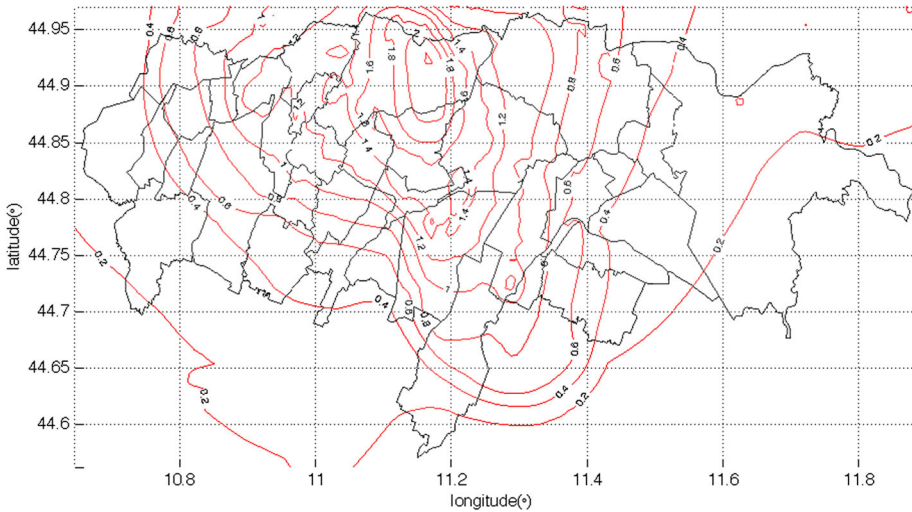


Fig. 7 Least squares fit of the four spectral acceleration samples

The  $i$ -th event acceleration spectrum has been assumed as the least square approximation of the reference functional form to the four samples of the  $i$ -th event. The errors within the min square procedure, as it will be later shown, are small and acceptable.

Figure 7 shows the least square approximation graphically for an example point, with coordinates longitude equal to  $11.387^\circ$  and latitude equal to  $44.903^\circ$ . The 475 years return period design spectrum is the black curve, the blue curve being 70% of this spectrum. The four INGV samples are the yellow rhombuses; the interpolating least square approximation is the red curve. Notice that all the drawn spectra never intersect. At any point on the territory, the requirement of the August 1st law issued by the Italian Chambers (2012), is either satisfied or not satisfied for all natural periods.



**Fig. 8** Level curves of the multiplication coefficient  $\alpha(lon,lat)$  of the Italian code reference spectrum

For step *iv*. In Sect. 2, notice that the least square approximation in Fig. 7 may be written as  $\alpha_a$  times the design response spectrum, i.e.  $S_{LS_i}(lon, lat) = \alpha_a S_{e_d}(lon, lat)$ ,  $S_{LS_i}$  being the least squares approximation to the *i*-th event four spectral samples, and  $S_{e_d}$  being the (reference) design spectrum. One may then define:

$$\alpha(lon, lat) = \max_i \{ \alpha_i(lon; lat) \} \tag{1}$$

and state that the exclusion area is defined by the (lon,lat) points such that  $\alpha(lon,lat) > 0.7$ .

This procedure has been entirely programmed in Matlab (2012), based on the INGV (2012) shakemaps data. Figure 8 shows the  $\alpha(lon,lat)$  level curves thus computed.

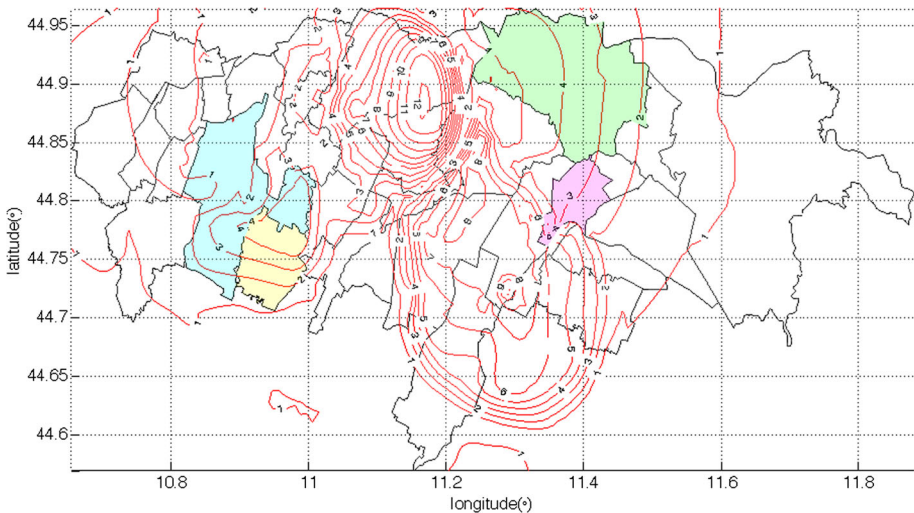
In order to check for the goodness-of-fit of the least square approximation, several controls have been performed, including comparison of results using different spectral shapes, with different soil types and with different return periods, or using different weights for different periods within the least squares approximation.

These controls can be shown in a very synthetic format if the level curves of the error, within the least squares approximation, are shown. With reference to Fig. 7, the error at each geographical point is defined as the average, at the four available periods, of the absolute value of the distance between the INGV spectral acceleration data (yellow rhombuses) and the least squares approximation (red curve). For each geographical point, only the event with the maximum  $\alpha_i$  is considered.

Figure 9 shows the error level curves corresponding to Fig. 8, i.e. assuming the 475 years return period, C soil type, design spectrum as the reference one. The level curves are similar to the  $\alpha$  level curves and generally show acceptable values.

### 4 Conclusions

Following the Emilia earthquake sequence of May–July 2012, the precast industrial buildings class was recognized as a highly fragile one. Many a collapse occurred, generally for lack of sufficient connection between columns and beams, and between beams and roof tiles.



**Fig. 9** Level curves of the errors (%) coming from least squares fitting

This prompted the immediate requirement, by the [Italian Government \(2012\)](#), of a generalized seismic retrofitting at a minimum of 60% of what was demanded for design of new buildings. The requirement applied to all the buildings of that class in the stricken area. This regulation looked however too severe, after considering that many an industrial building had been stricken by a more intense earthquake, and had shown no damage; furthermore, this was inconsistent with what was demanded for existing structures in Italy, whose owners are compelled to comply with the Italian seismic code only if a change of load or usage was required.

In order to speed up community recovery, the Authorities decided to relax the original requirements, and the August 1st regulation ([Italian Chambers 2012](#)) removed obligation to seismic retrofit the industrial buildings that had shown no damage and had been stricken by an earthquake whose response spectrum was at least 0.7 times the design one.

This paper describes the procedure followed in order to define the territorial extension involved in the second regulation.

The procedure set up has taken advantage of the soil homogeneity in the Emilia area; certainly, the small number of recording instruments available in the area of the events of May 20th has been the major drawback. The subsequent events, with many more recording instruments, control on the approximation introduced within the procedure via the experimental data interpolation used, and the soil homogeneity in Emilia have allowed computation of reasonably accurate results, through a simple procedure.

This application is, to the authors' knowledge, the first one on this scale. It aims to speed up community recovery and preserve structural safety at the same time, and could be used in the future as an effective means to minimize the indirect earthquake effects.

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