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INTERACTIVE WEB-BASED SOFTWARE FOR THE SEISMIC SAFETY ASSESSMENT OF SPECIAL IMPORTANCE BUILDINGS: ASSEE

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ABSTRACT

The Institut Cartogràfic i Geològic de Catalunya (ICGC) has developed the ASSEE software to contribute to the seismic risk analysis at municipality scale in Catalonia (NE of Spain). Its goal is to provide municipality technicians with a tool that can easily help them identify the buildings with higher seismic risk considering the local seismic hazard of the region. The interactive web-based software, ASSEE, integrates a methodology for the seismic safety assessment of special importance buildings that evaluates if a building would comply with the required seismic performance levels.
In ASSEE, seismic action is defined by the results of the probabilistic seismic hazard assessment for the region that will be included in the next update of the Spanish seismic normative. Site effects are included based on the results of a seismic mesozonation of Catalonia. Expected damage is obtained applying a simplified methodology based on the capacity spectrum method and the structural typologies identified by the user. Then the software performs the capacity spectrum method and calculates the expected damage distribution for return periods of 475 and 975 years. Finally, the safety of the special importance buildings is evaluated for both return periods as suggested in Valcárcel (2013).
The seismic safety assessment from ASSEE allows identifying the special importance buildings at higher risk of not performing satisfactorily. This evaluation represents a first step toward a more detailed performance evaluation of these buildings that can lead to the application of vulnerability reduction policies to ensure that the desired seismic performance is fulfilled.

Keywords: risk; safety; performance; essential; software

1. INTRODUCTION

The seismic emergency management plan for the Catalonia region, SISMICAT (2003), analyses the seismic risk at the municipality scale. The municipalities with significant seismic risk were identified and required to draft their own and more detailed seismic emergency action plans. As part of this local seismic action plans, municipalities are expected to identify the buildings that are of special importance and evaluate their seismic risk. In order to contribute to the development of these detailed seismic action plans, ICGC has created an interactive software that allows users to evaluate the seismic risk and performance safety for buildings of especial importance. This software is known as ASSEE (Avaluació de la Seguretat Sísmica d'Edificis d'Especial importància, in Catalan) which stands for evaluation of the seismic safety of special importance buildings.
The ASSEE software implements the methodology for the seismic safety evaluation developed by Valcárcel (2013) which consists of a simplified application of the capacity spectrum method for evaluating the seismic safety of buildings of special importance such as hospitals and schools. This methodology includes guidelines for estimating the seismic action expected to affect the building and for evaluating its expected seismic performance, probable seismic damage and its associated level of

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safety. This evaluation allows identifying the essential buildings that have a high seismic risk and that are in need of a more detailed risk analysis to determine possible risk mitigation actions.
The ASSEE software has been developed and is now in a test phase. The user only has to specify the basic information for the special importance building to be analyzed and the ASSEE software will perform the whole seismic safety evaluation in just a few clicks. Soon it will be available to be used through the Internet by municipality officials who will be able to perform fast preliminary seismic safety evaluations of individual buildings identified as of special importance for the municipality.

2. SEISMIC SAFETY EVALUATION

As recommended by Valcárcel (2013), the seismic safety assessment included in ASSEE is based on the performance based requirements suggested by the Vision 2000 Committee (SEAOC, 1995) that are summarized in Table 1. According to the Committee, the special and important buildings are expected to exhibit a better performance than normal buildings as they should remain at least operational after a rare seismic event, one with a return period of 475 years, and not to collapse during a very rare seismic event associated to a return period of 975 years. In terms of performance levels, these requirements imply that these buildings should comply with the Operational performance level (light to moderate damage) for a return period of 475 years and Life Safety (moderate to extensive damage) for a return period of 975 years.
ASSEE uses the expected mean damage grade to evaluate if the considered building meets the seismic performance levels suggested by the Vision 2000 Committee. Valcárcel (2013), considering the damage scale suggested by Rossetto and Elnashai (2003), stated that a maximum mean damage grade of 2.0 for a return period of 475 years is allowed to be expected to comply with the Operational performance level and a maximum mean damage grade of 2.8 is used to determine if the buildings are expected to meet the Life Safety performance level. Considering the normalized mean damage grade, these maximum values correspond to 0.5 and 0.7, respectively.

Table 1. Performance levels suggested by the Vision 2000 Committee (SEAOC 1995).

Performance Level	**Description**	**Damage State**	**Return Period (Years)**
Fully Operational	Continuous service, facility operates and functions after the earthquake. Negligible structural and non-structural damage.	No Damage	72
Operational	Structure is safe for occupancy immediately after the earthquake. Most operations and functions can resume immediately. Repair is required to restore some non-essential services. Damage is light.	Reparable	475
Life Safety	The structure is damaged but remains stable and life safety is generally protected. Damage is moderate. The building can probably be repaired, but it may not be economically feasible.	Probably Reparable	975

So in order to evaluate the seismic safety of a certain special importance building, we need to estimate the expected mean damage grade associated to return periods of 475 and 975 years. In this sense, the ASSEE methodology integrates the capacity spectrum method to evaluate the mean damage grade, estimating the required capacity curve for the structure from its structural typology and providing a site specific response spectrum including site effects for return periods of 475 and 975 years depending on the location of the studied building within the Catalonia region (Figure 1).

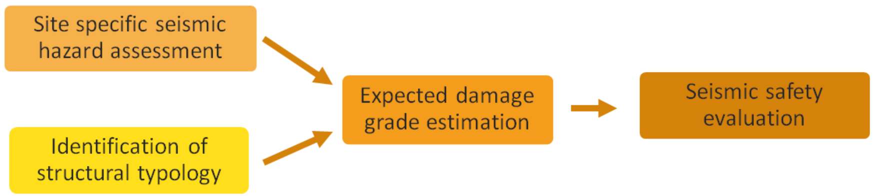
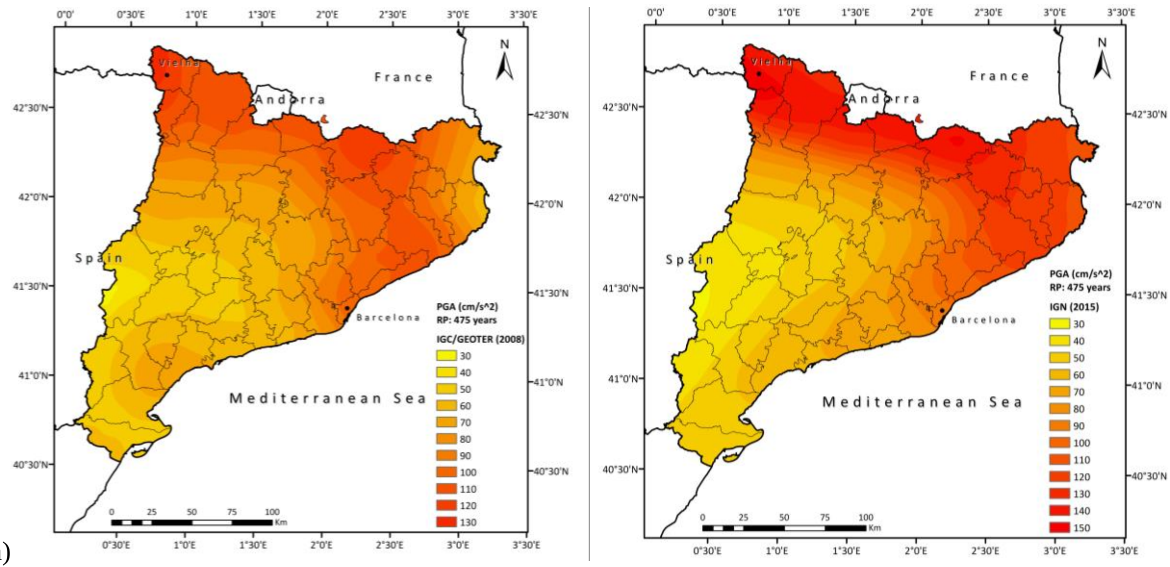


Figure 1. Summary of the seismic safety evaluation.

The methodology proposed by Valcárcel (2013) also estimates other parameters to assess the possible impact of the expected damage on the services offered by the special importance buildings analyzed. These parameters include an economic loss index, a functionality index and an estimate of the recovery time. The first one depends on the expected damage probability distribution while the other two depend on the mean damage grade obtained (Irizarry et al. 2014).

2.1 Seismic Hazard

The local seismic action used for seismic hazard evaluation comes in the form of acceleration response spectra. Nowadays, the acceleration response spectra included in the ASSEE software are derived from the Probabilistic Seismic Hazard Analysis (PSHA) developed for Catalonia (IGC and GEOTER 2008). This study produced spectral acceleration maps for various structural periods that allow to construct acceleration response spectra for any site in Catalonia for return periods of 475, 975 and 1975 years, not only for mean values but for several other percentiles. In the current version of the Spanish seismic normative (NCSE 2002), the accelerations recommended for the Catalonia region are lower than those obtained by the ICGC and GEOTER (2008) study. The later was considered as a best representation of the seismic hazard of the region and was integrated in the ASSEE software.
A new PSHA map for Spain (Martinez et al. 2012; IGN 2015), that is expected to be the basis for the seismic loading in the future version of the Spanish seismic normative, has been recently published. As this new PSHA estimation for Spain represents a higher seismic hazard than the IGC and GEOTER (2008) study (Figure 2) and because it will be considered the standard for seismic design in Spain, ASSEE will be modified to consider this new study for selecting the acceleration response spectra for the analysis.



a) b)

Figure 2. Comparison between the PGA maps for a return period of 475 years from both (a) the IGC and GEOTER (2008) PSHA study and (b) the new PSHA evaluation for Spain from IGN (2015).

2.2 Soil effects

Soil effects are considered based on the seismic mesozonation map of Catalonia (MSC) (IGC 2013) at a scale of 1:100,000 (Figure 3). The seismic mesozonation map is a simplification of the geological map based on the soil classification according to the seismic amplification potential. This soil classification is inspired on the Eurocode 8 (CEN 2004) but adapted to the specific soils identified in the Catalonia region. It was developed within the context of the SISPYR project and considers the soil geomechanical characteristics, its thickness and the contrast velocity of the adjacent layers. The soil classification of the Catalonia mesozonation includes a total of 7 soil classes for which the typical layer's configuration are shown in Figure 4.

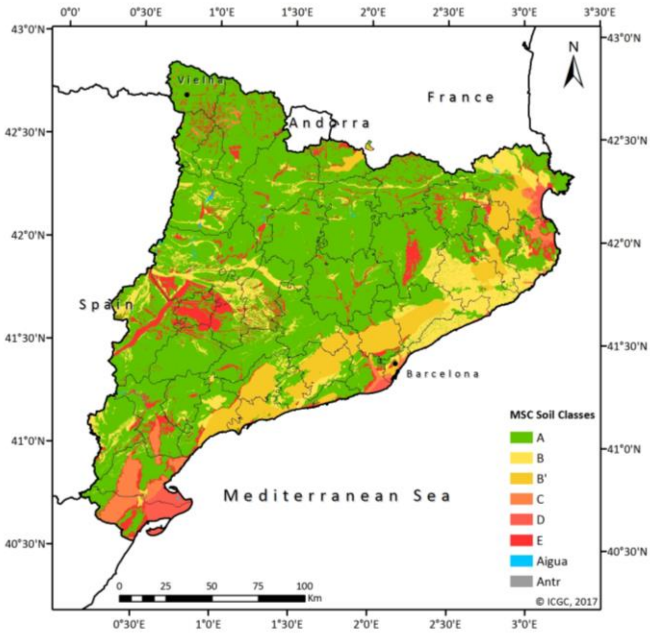


Figure 3. Seismic mesozonation map of Catalonia (MSC), scale 1:100M

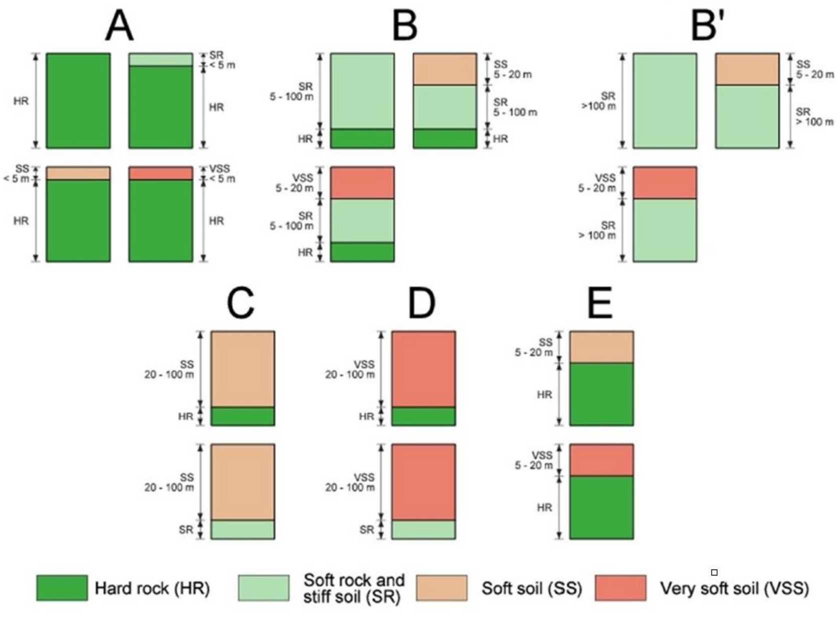


Figure 4. Soil classes identified in the seismic mesozonation study of Catalonia.

The seismic site effect of each soil class was evaluated within the scope of the project SISPYR (2013). A normalized acceleration response spectrum including soil effects was obtained for each one of the soil classes allowing in this way to obtain a local acceleration response spectrum adequate to the soil conditions for each of the special importance buildings being analyzed (Colas et al. 2012; IGC 2012b). These normalized acceleration response spectra with soil effects are shown in Figure 5.

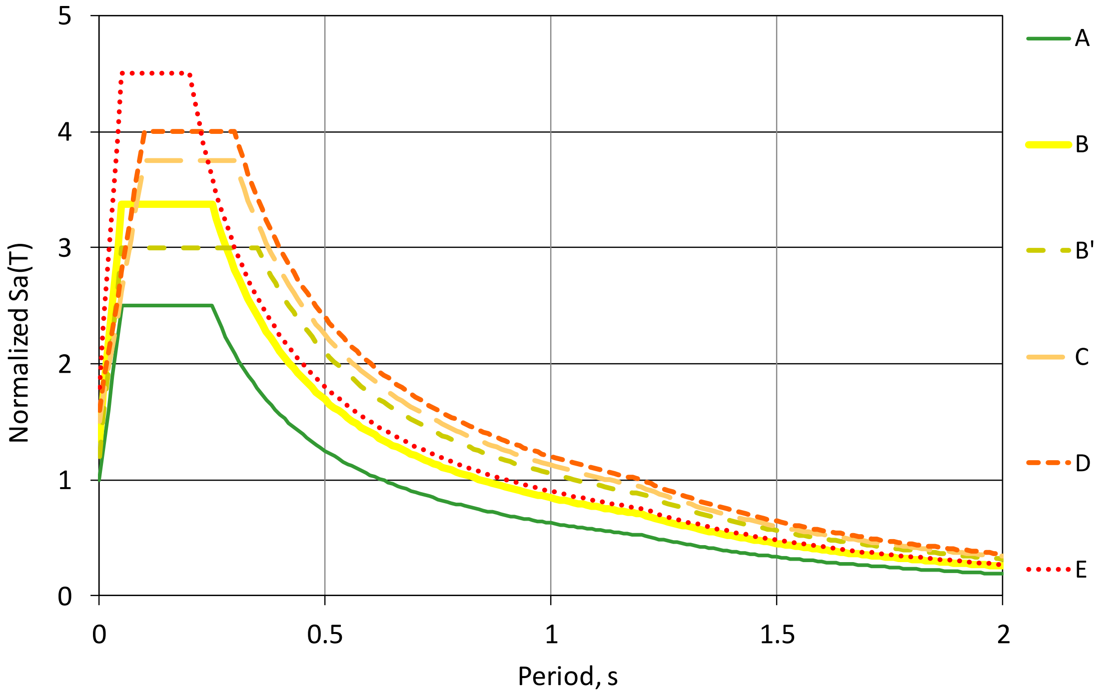


Figure 5. Normalized acceleration response spectra for each mesozonation soil class (Colas et al., 2012).

2.3 Defining the structural typology

The methodology implemented in ASSEE requires identifying the structural typology of the building being analyzed. Such identification of the structural typology can be achieved by performing a visual inspection of the buildings in order to establish their main structural properties and analyzing construction memories and both architectonic and structural plans. For Catalonia there are available seismic vulnerability forms that can contribute to this objective (IGC and UPC 2010).
The ASSEE methodology includes a set of structural typologies for which both a bilinear capacity spectrum and the corresponding fragility curves were selected by Valcárcel (2013) from the available literature.
This set of typologies was selected from previous projects, such as RISK-UE (Mouroux et al. 2004) and ISARD (Roussillon et al. 2006), that were dedicated to identify the most representative types of buildings in the region. It includes 9 types of masonry structures, 7 types of concrete structures, 6 types of steel structures and one for wood. For most of these structural typologies 3 height intervals are considered and specific capacity and fragility curves are included for each one.

2.4 Evaluating the expected seismic Damage

The ASSEE methodology uses the capacity spectrum method to evaluate the expected seismic damage related to the seismic actions associated to return periods of 475 and 975 years. Once the structural typology is selected, a capacity spectrum is assigned to each of the special importance buildings studied. Then, the performance point, the intersection between the capacity spectrum and the correspondent demand spectrum, is estimated following the equal displacement approximation as

suggested in the RISK UE project (Figure 6a).
The displacement of the performance point allows obtaining the damage probability distribution using fragility curves available for each structural typology as indicated by Valcárcel (2013). The fragility curves (Figure 6b) define the probability that the expected damage exceeds a specific damage grade. Four damage grades are considered: 1-light, 2-moderate, 3-extensive and 4-complete. Once the damage probability distribution is obtained, the mean damage grade can be calculated as the weighted mean of the damage states with respect to its corresponding probability. The mean damage grade value will allow evaluating the seismic safety level of the studied essential building.

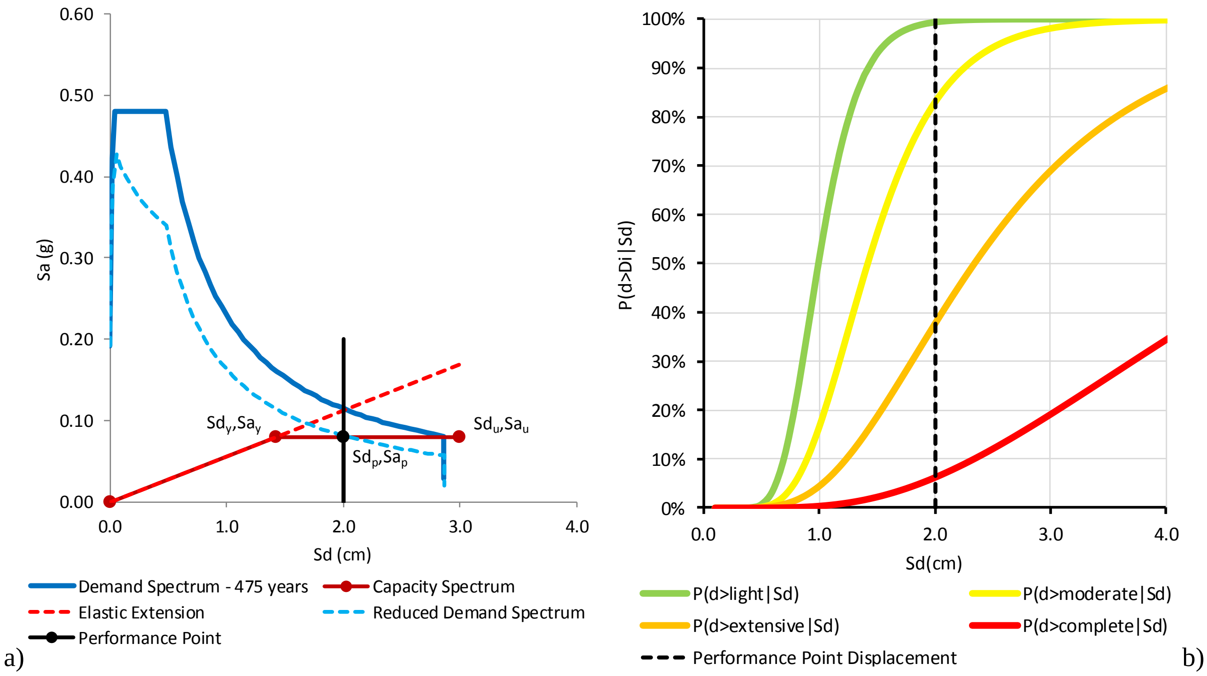


Figure 6. a) Determination of the performance point using the capacity spectrum method and b) Example of the fragility curves used to obtain the damage probability distribution.

3. ASSEE SOFTWARE

ASSEE has already been developed and now is being tested in its web platform. Also some new inputs are being adapted to the software and the user manual is being drafted. When fully ready, it will be only available to registered users who will only have to enter some basic info of the analyzed building to obtain a detailed evaluation of the expected seismic damage and safety for return periods of 475 and 975 years following the presented methodology from Valcárcel (2013).

3.1 System architecture

The ASSEE system has been developed using Ruby on Rails (Ruby programming language framework on Rails framework). The database to store and manage the software data and metadata is PostreSQL, including the PostGIS extension for the geospatial information.
The web pages making up the Graphical User Interface (GUI) are W3C compliant and have been developed using HTML5 language. Furthermore, CSS 3 format and Javascript language are used to define the visual styles and the available interactive options. AlsoTwitter Boostrap 3 is used for the website design and layout. The GUI includes the Google API v3 to display available ortophotos and maps from configured WMS server allowing the user to visually select the building to be evaluated so the system automatically determines its geolocation and address fields, simplifying the data entry process.

Besides the user interface designed for data input, ASSEE also has a web interface to manage the application. This administrator interface allows reviewing and updating all the internal data used by ASSEE to perform the seismic safety evaluation. The internal data that can be updated includes: seismic hazard maps (PGA) for different return periods, soil effects maps, soil classes, structural typologies, both capacity and fragility curves and the text interpretation of the numerical results of the safety evaluation depending on the values of the different parameters considered. This interface also allows managing users that are allowed to access de web-based software.

3.2 Input data

The ASSEE user will have to provide some basic information about the structure to be analyzed. After signing in to the web platform, the user access the input page (Figure 7) where all the input data about the building is collected. The input data about the building includes the name, address, municipality, UTM coordinates, economic value, number of occupants, structural typology and the soil class of its site. The minimum data required for the software to run is indicated with an asterisk (*). These minimum requirements include the coordinates of the building location, its structural typology and the soil class of the site.

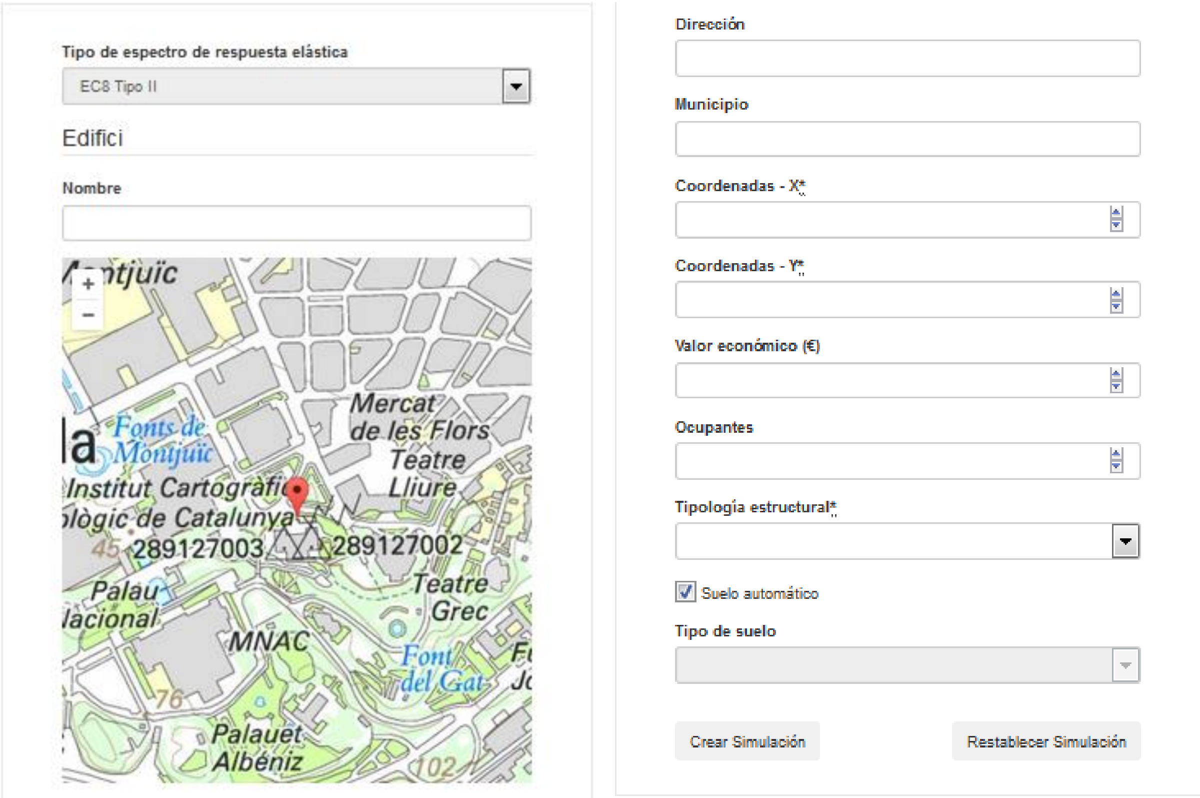


Figure 7. Example of an ASSEE's input page.

Some provisions have been taken to help the user identify the coordinates and the soil class for the safety analysis. ASSEE can determine these variables automatically based on the location of the building or the user can chose to enter them manually. In the case that coordinates are unknown, the user can visually search the building in the available map and by clicking on it the address, municipality and coordinates fields will be filled automatically. When no site specific information is available to determine the soil class where the building stands, the user can activate the automatic soil class identification and ASSEE will locate the soil class for the site by locating it in the seismic mesozonation map of Catalonia.

3.3 Results

Few seconds after hitting the “create simulation” button, the user will obtain the results to review on screen in a summary report as proposed by Bosch (2013) and Irizarry et al. (2014). These results must be printed or downloaded in PDF format to be saved by the user as there is no user account or database for ASSE to store them.

The results report consists of 3 pages. The first page presents the results of the whole process of the seismic safety evaluation for a return period of 475 years, while the second does the same but for a return period of 975 years (Figure 8a). The third page of the results report provides a comparative summary of the results for both return periods and the analysis of the seismic safety of the structure (Figure 8b).

a)

b)

Figure 8. Example of results: (a) 975 years return period and (b) comparative summary and safety evaluation.

The page with the results for each return period shows the information used to define the seismic action including the soil class, the method of soil class selection and the peak ground acceleration both for rock and soil conditions. It also shows the structural typology selected and performs a graphical representation of the capacity spectrum method showing the intersection of the demand and capacity spectra to determine the performance point which is indicated in the report (Figure 9). Additional graphics show the fragility curves considered and the obtained damage probability distribution. Finally, the mean damage grade expected for the analyzed building along with the economic and functionality indexes and the estimated recovery time are reported in a table.

The summary page of the report compares the seismic action, performance point, damage probability distribution, the mean damage grade and the other evaluated parameters for the return periods of 475 and 975 years. The final part of this page shows the safety evaluation of the building stating if it fulfils the requirements for the Operational and Life Safety performance levels proposed by the Vision 2000 Committee. This evaluation is presented both in written and graphical forms as can be seen in Figure 10. If the bar representing the expected mean damage grade for the different return periods does no reach the corresponding mean damage grade limits, then the structure is expected to meet the safety requirements considered. As a final remark text interpretations of the numerical results obtained are given as predefined in the ASSEE software.

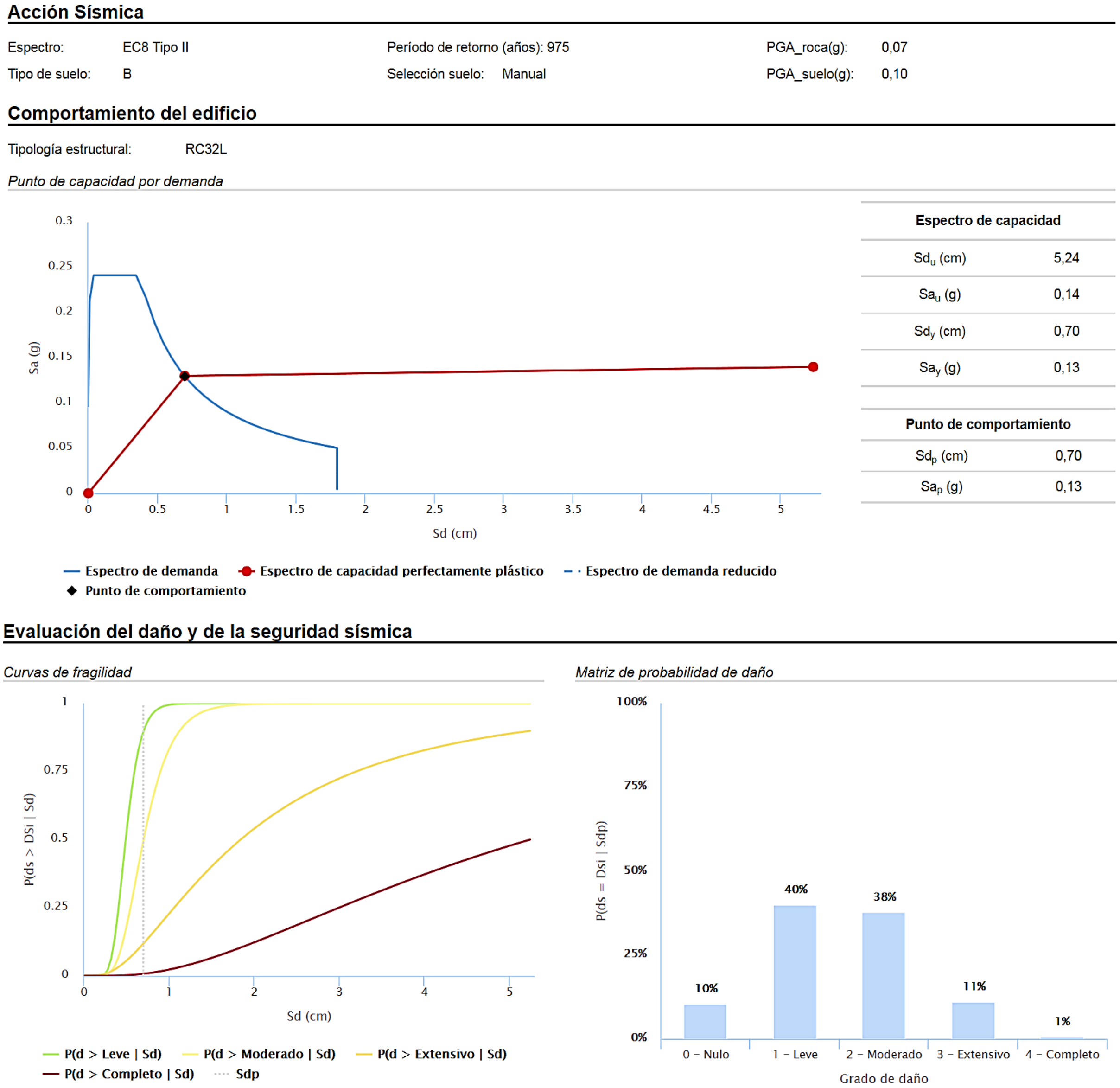


Figure 9. Example of expected damage results for a return period of 975 years.

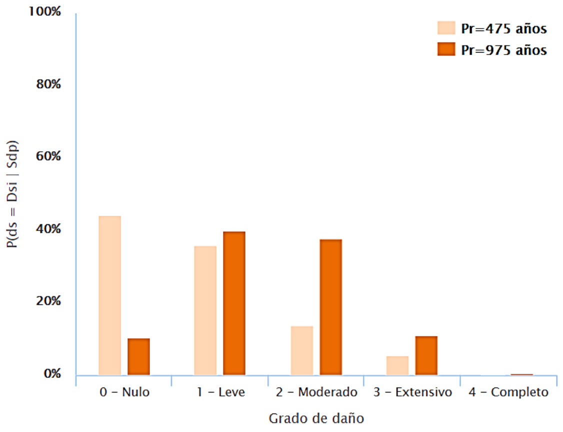
3.4 Advantages and limitations

Some advantages stand out of having software that integrates the seismic safety evaluation methodology as ASSEE does. The ASSEE software simplifies the process of the seismic safety evaluation so municipality technicians are able to make a preliminary evaluation of the seismic risk and expected performance of the special importance buildings. As ASSEE is available through the Internet and hosted at a server at the ICGC, the seismic hazard map, mesozonation map and capacity and capacity and fragility curves can be updated through its administrator web interface. In this way, users can always make their evaluations with the most update information available.

One limitation of the ASSE tool is that the proposal for the safety evaluation of the seismic safety is based on structural typologies only modified by height ranges in some cases, it is considered as a first step to identify the buildings that are at more risk. Once identified, a more detailed analysis is required to analyze the complete structure including also the effect of the possible expected nonstructural damage

Evaluación del daño

Matriz de probabilidad de daño



Pr(años)	0 - Nulo	1 - Leve	2 - Moderado	3 - Extensivo	4 - Completo
475	44%	36%	14%	6%	0%
975	10%	40%	38%	11%	1%

Evaluación de la seguridad

Índices				
Pr (años)	Grado de daño medio [0-4]	Índice de pérdida (%)	Índice de funcionalidad [0-1]	Tiempo de recuperación (dias)
475	0,8	24,0	0,9	64
975	1,5	31,1	0,5	119

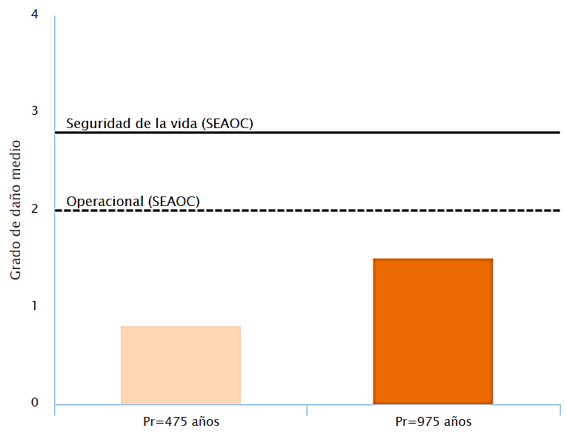


Figure 10. Example of results comparison in the summary report.

4. CONCLUSIONS

The interactive web-based software, ASSEE, for the seismic safety assessment of special importance buildings in Catalonia is already developed and being tested. The methodology proposed by Valcárcel (2013) for the seismic safety assessment implemented in this software provides a useful and simplified version of the capacity spectrum method in order to facilitate its application to individual structures without having to develop the fully detailed models and structural analysis required by its original version. The use of the mean damage grade to verify the fulfilment of the Vision 2000 Committee performance requirements, as proposed by Valcárcel (2013), provides an easy tool to implement criteria for achieving this objective.
The seismic safety assessment provided by the software ASSEE, as well as the estimation of the expected losses, etc., represents a preliminary evaluation of the seismic risk of an especial importance building that can be extremely useful for screening purposes. Those structures that do not comply with the proposed performance levels should then require a more detailed structural analysis in order to identify its possible weak points and be able to enhance its seismic performance and safety. For such reason, the ASSEE software constitutes a useful tool for the municipality officials in charge of the seismic risk assessment of especial importance buildings needed for drafting the municipal seismic action plans.

5. REFERENCES

Bosch A (2013). Avaluació de la seguretat sísmica dels edificis d'especial importancia, *Master Thesis*, Universitat Politècnica de Catalunya, Dept. Enginyeria del Terreny, Cartogràfica i Geofísica, Barcelona. 312pp.

CEN (2004). Eurocode 8: Design of structures for earthquake resistance – Part 1: General rules, seismic actions amb rules for buildings, European Committee for Standardization, EN 1998-1:2004.

Colas B, Goula X, Roullé A, García I, Buxo P, Roviró J, Dewez T, Nus E (2012). Shake-Map Site effect corrections, Project Sispyr Report Nº 10, Available on www.sispyr.eu, Last consulted on October 2017.

ICGC, GEOTER (2008). Càlcul probabilista de la perillositat sísmica a Catalunya en acceleracions espectrals. Document GTB/IGC/0508-001, Institut Geològic de Catalunya, Barcelona, Spain.

IGC (2012a). Microzonació sísmica de nivell avançat a l'àrea urbana de Girona. SYSPIR, Report IGC-GA-009/12, Institut Geològic de Catalunya, Barcelona, Spain, 67pp.

IGC (2012b). Shake-Map: Site effect corrections, Institut Geològic de Catalunya Informe IGC-GS-021/12, Institut Geològic de Catalunya, Barcelona, Spain, 182pp http://bit.ly/2rycRMA, Last consulted on June 2017

IGC (2013). Mapa de Mesozonació sísmica de Catalunya (1:100 000), adaptat a la classificació EC8 (versió 2013), Institut Geològic de Catalunya, Barcelona, Spain, Report IGC-GS-001/13, 46pp.

Irizarry J, Bosch A, Valcarcel JA, Jara JA, Barbat AH, Pujades LG, Goula X (2014). Interactive Web-Based Software for Seismic Safety Assessment of Special Importance Buildings. *Proceedings of the 2nd European Conference on Earthquake Engineering and Seismology*, 24-29 August, Istanbul, Turkey.

Macau, A. (2008). Microzonación sísmica. Contribución a los estudios de peligrosidad sísmica a escala local en zones rurales y urbanas. *Ph.D. Thesis*, UPC, 328pp.

Martinez Solares JM, Cabañas L, Benito MB, Rivas A, Gaspar JM, Ruíz S, Rodríguez O, (2017). Actualización de mapas de peligrosidad sísmica de España 2012, Centro Nacional de Información Geográfica i Instituto Geográfico Nacional, Madrid, Spain, Last consulted on june 2017 http://www.ign.es/web/ign/portal/publicaciones-boletines-y-libros-digitales#publication_4

Mouroux P, Bertrand E, Bour M, Le Brun B, Depinois S, Masure P, the Risk-UE team, (2004). The European Risk-UE project: and advanced approach to earthquake risk scenarios. *Proceedings of the 13th World Conference on Earthquake Engineering*, Vancouver, B.C., Canada, August 1-6, 2004.

NCSE-02 (2002). Real Decreto 997/2002, de 27 de septiembre, por el que se aprueba la norma de construcción sismorresistente: parte general y edificación (NCSR-02). Ministerio de Fomento. Publicaction date: 11-10-2002. BOE: 244-2002, pp. 35898-35966.

SEAOC (1995). Vision 2000 – A framework for performance based earthquake engineering. *Structural Engineers Association of California*, Vol. 1, January.

SISMICAT (2003). Pla especial d'emergències sísmiques a Catalunya, 33p. Available on http://www.gencat.net/interior/esc/docs/esc_sismicat.pdf (in Catalan).

SISPYR (2013). Project SISPYR: Seismic Information System for the Pyrenees, www.sispyr.eu, Last consulted on October 2017.

Rossetto T, Elnashai A. (2003). Derivation of vulnerability functions for European-type RC structures based on observational data, *Engineering Structures* (25), 1241–1263.

Roussillon P; Irizarry J; González M; Delmotte P; Sedan O; Susagna T, (2006). Cross-border seismic risk scenarios (Eastern Pyrenees), *First European Conference on Earthquake Engineering and Seismology*. Paper Number: 902, Geneva, 2006

Valcárcel JA (2013). Análisis y gestión del riesgo sísmico de edificios y sistemas esenciales, *Ph.D. Thesis*, Universitat Politècnica de Catalunya, Dept. Enginyeria del Terreny, Cartogràfica i Geofísica, Barcelona. 301pp.