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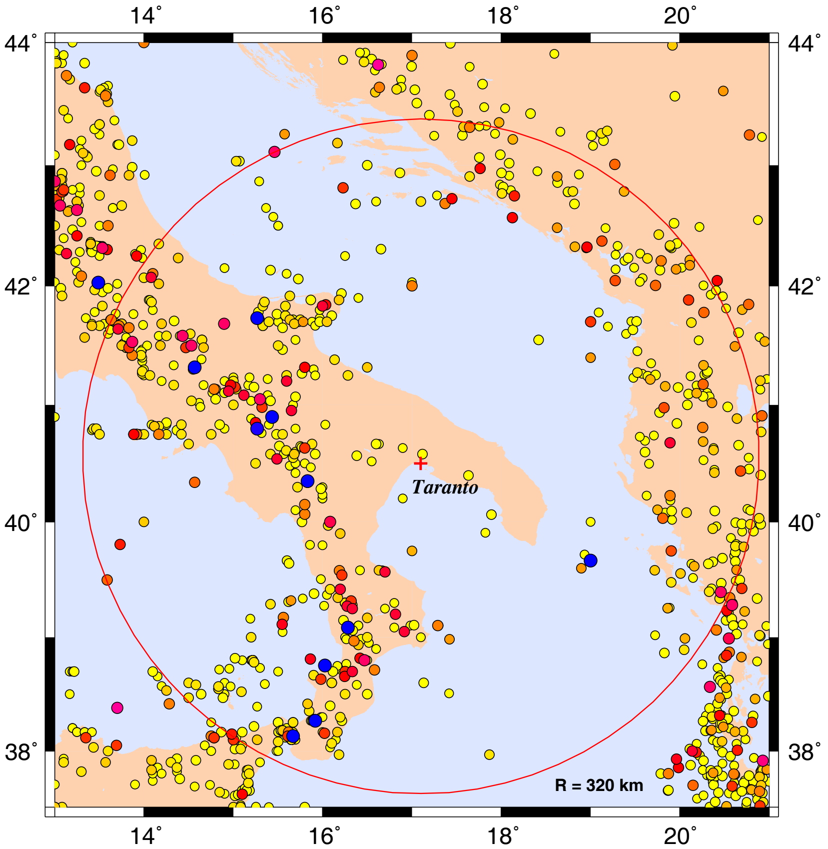


**LNG PLANT AT TARANTO (ITALY)**

# SUMMARY OF SEISMIC HAZARD EVALUATION

Report

to

Gas Natural

Report no. 674
Project no. P-373
19/01/05

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|---|---|---|
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# 1. INTRODUCTION

## 1.1 Preamble

Gas Natural is planning to construct an import and regasification plant for liquefied natural gas (LNG) at Taranto. The installations provide a regasification capacity of $8 \times 10^9$ $Sm^3$/year.

The requirements expressed in section 4-1.3 of NFPA 59-A (National Fire Protection Association, 2001) and in the European Standard EN 1473 (CEN, 1997) make it necessary to determine the seismic hazard at the site prior to designing the facilities.

The present report summarizes the results obtained in the context of the above requirements and provides the characteristics of the seismic motions to be used in the design of the plant. A full account of the investigations conducted has also been produced (Principia, 2005).

## 1.2 Object

The first objective of this report is to present the evaluation of the seismic hazard at the site. This hazard is quantified by means of the seismic hazard curve, which expresses the annual probability of exceeding each acceleration at the site. A relatively recent methodology is implemented for determining of the seismic hazard curve. This procedure uses a “zoneless” approach, which overcomes many of the paradoxes and inconsistencies of more traditional methodologies that rely on the construction of seismogenetic zones of uniform activity.

Second, based on the corresponding return periods and on the hazard curve obtained, the next objective is to establish the peak acceleration levels for the two design earthquakes: the operating basis earthquake (OBE) and the safe shutdown earthquake (SSE).

Thirdly, site specific response spectra must be adopted for the design. These are primarily governed by the local geotechnical conditions and their shape has to comply with the relevant standards and guidelines.

# 2. EVALUATION OF THE HAZARD

## 2.1 Description of the methodology

The zoneless method used follows the ideas proposed by Woo (1995, 1996a). The numerical implementation is that embodied in the computer program KERFRACT (Woo, 1996b). The procedure is the same one already employed for determining the seismic hazard at all other sites with LNG tanks in Spain (Crespo and Martí, 2002), as well as some LNG plants abroad like Dahej (India), Damietta (Egypt) or Lázaro Cárdenas (Mexico).

The basic starting data are the catalogue of past epicentres and their corresponding magnitudes, together with the knowledge of the effective period of observation for each magnitude (Figure 2–1). This allows constructing an activity rate for each location and event magnitude. The activity rate is obtained by adding the individual contributions of all events in the catalogue.

Attenuation laws are used to calculate, for the earthquakes that occur at distances less than 320 km from the site, the motions that would be felt at the location of the plant. The laws adopted in the present study follow those proposed by Sabetta and Pugliese (1987, 1996). The simultaneous consideration of the activity throughout the region of influence, together with the appropriate attenuation laws, yields the seismic hazard at the site.

## 2.2 Seismic hazard at the site

The above methodology generates results, directly in terms of acceleration, for each return period or annual probability of exceedance. The hazard curve generated, providing the accelerations associated with each probability of occurrence is shown in Figure 2–2. The accelerations obtained correspond to zero period.

The local ground characteristics are taken into account in the generation of the hazard curve; for this purpose, the information reported by Soil (2005) has been used. A shallow soil “description has been adopted laws proposed by Sabetta and Pugliese (1987, 1996).

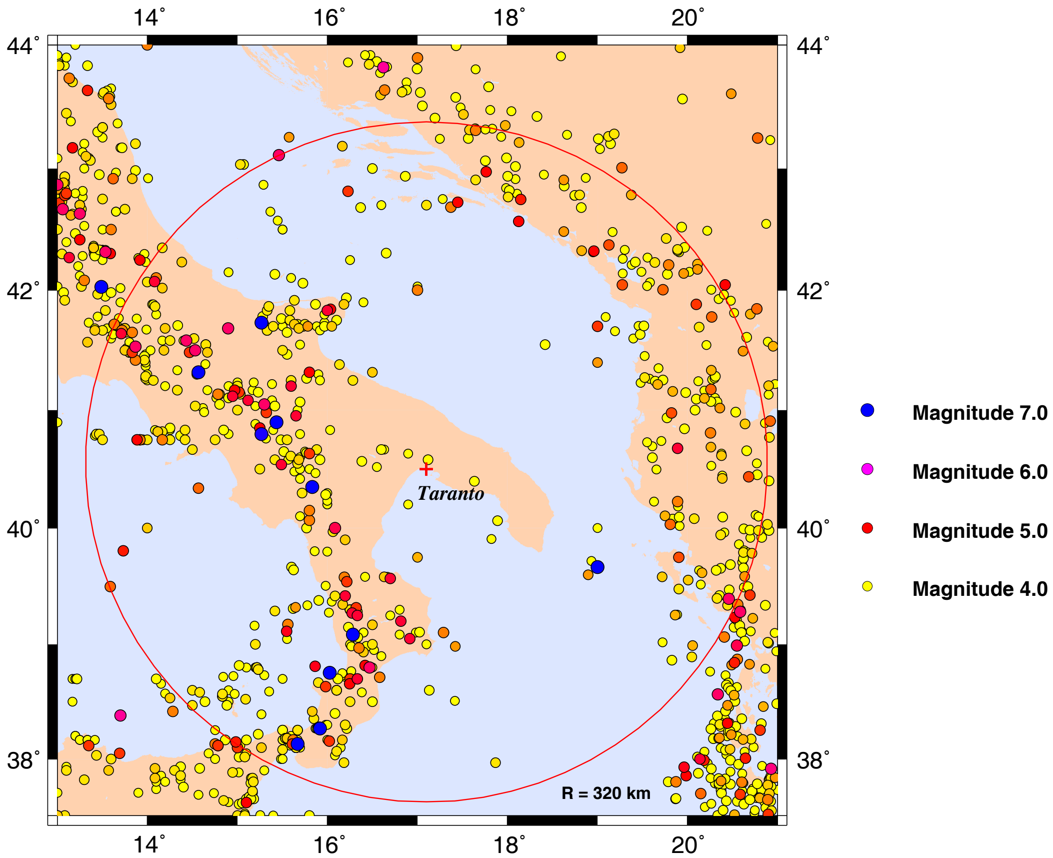



Figure 2–1 Epicentres with M ≥ 4 and 320 km circle

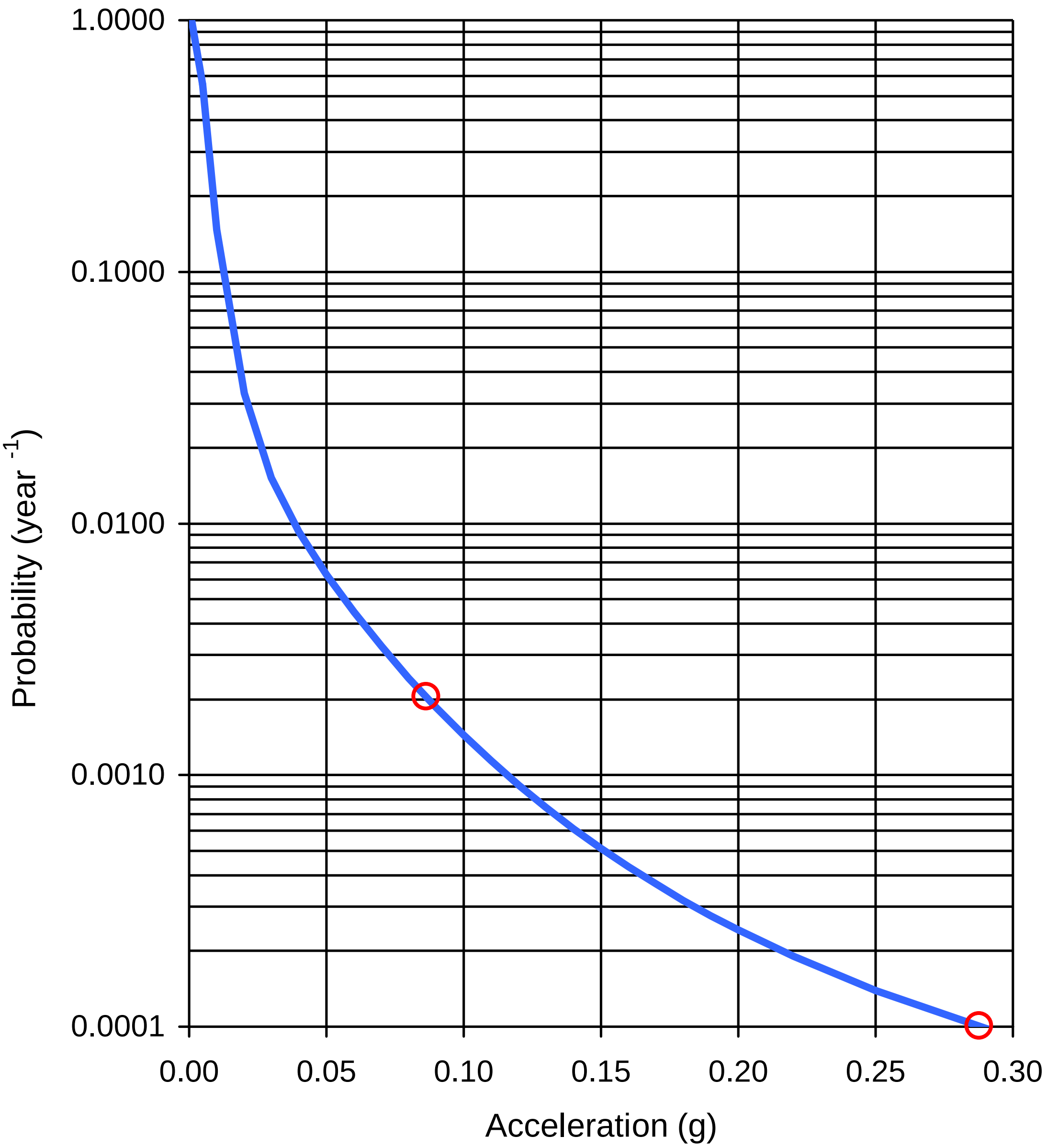



Figure 2–2 Spectral acceleration, $T = 0$ s

# 3. DESIGN MOTIONS

## 3.1 Design accelerations

The seismic hazard curve for the site was already shown in the previous chapter. For design, though, this information must be combined with the corresponding periods in order to arrive at the peak ground accelerations for the OBE and SSE motions. The return periods for the two design earthquakes are 475 years for the OBE and 10,000 years for the SSE. This latter period is the one adopted by the NFPA 59–A (NFPA, 2001) until 2001 and that EN 1473 (CEN, 1997) still maintains. This period can be considered conservative, since the revised NFPA 59–A reduces it. In any case, taking into account that the site is in Europe, EN 1473 should be adopted in case of conflict between the two norms.

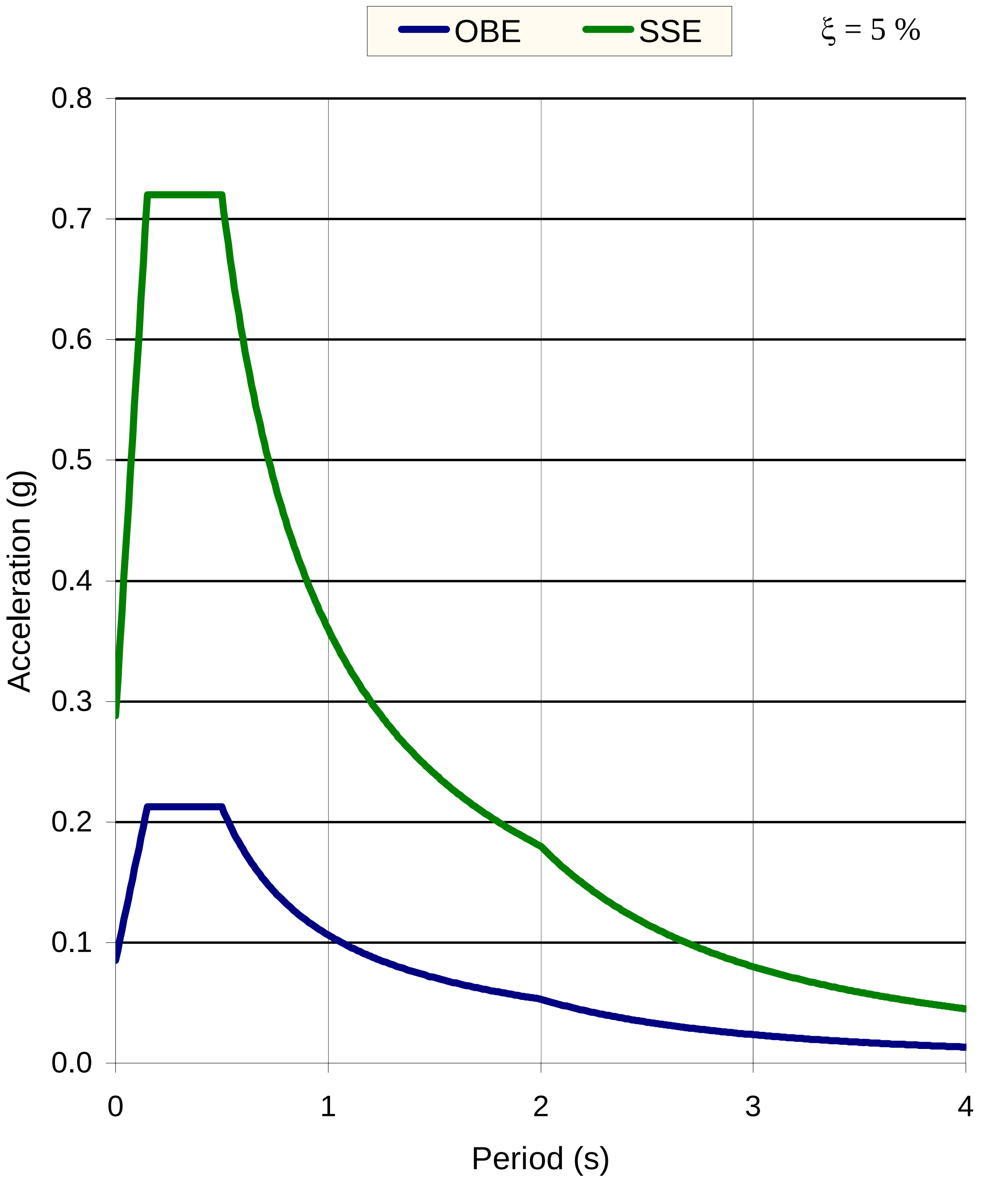
As can be seen in Figure 2–2, the calculations lead to adopting a peak horizontal ground acceleration of 0.09g for the OBE and 0.29g for the SSE.

## 3.2 Site specific response spectra

The response spectrum describes the frequency distribution of the ground motion. It is defined as the motion amplification that an elementary oscillator would experience as a function of the frequency to which it was tuned.

OPCM (2003) establishes five different soil profiles, as a function of the local shear wave velocity. The spectra developed here correspond to soil type C in OPCM (2003), deposits of dense or medium dense sand and gravel or medium consistency clay, according with the information produced by Soil (2005). The maximum acceleration of the soil of the site is was presented in section 3.1 for different return periods. Following OPCM (2003) this acceleration may be expressed as $S \cdot a_g$, where the factor $S$ = 1.25 takes into account the soil profile

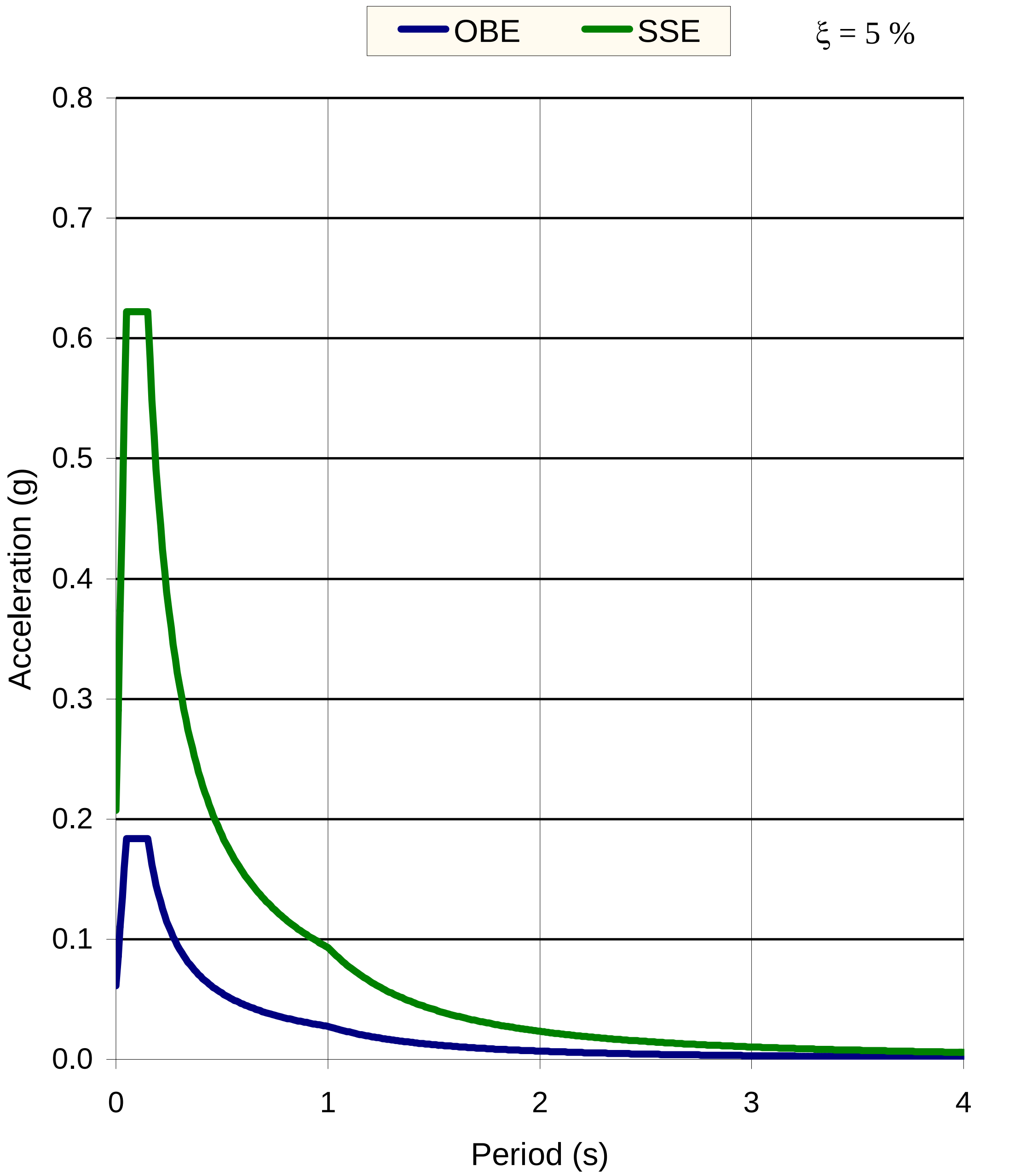
Consistently with the provisions of OPCM (2003), the horizontal spectra for the OBE and SSE earthquakes have been developed and are presented in Figure 3–1. Also applying the norm, the resulting vertical spectra are those shown in Figure 3–2.




| T (s) | 0.00-0.15 | 0.15-0.50 | 0.50-2.00 | > 2.00 |
|---|---|---|---|---|
| OBE | $\left[1.0 + \frac{20}{3} T(2,5\eta - 1)\right] 0.09$ | $0.225\eta$ | $0.1125 \frac{\eta}{T}$ | $0.225 \frac{\eta}{T^2}$ |
| SSE | $\left[1.0 + \frac{20}{3} T(2,5\eta - 1)\right] 0.29$ | $0.725\eta$ | $0.3625 \frac{\eta}{T}$ | $0.725 \frac{\eta}{T^2}$ |

Damping correction factor: $\eta = \sqrt{\frac{10}{5+\xi}}$ with $\eta \geq 0.55$

Figure 3–1 Horizontal OBE and SSE spectra




| T (s) | 0.00-0.05 | 0.05-0.15 | 0.15-1.00 | > 1.00 |
|---|---|---|---|---|
| OBE | $[1.0 + 20 \cdot T \cdot (3.0 \cdot \eta - 1)]\, 0.0648$ | $0.1944 \cdot \eta$ | $0.02916 \dfrac{\eta}{T}$ | $0.02916 \dfrac{\eta}{T^2}$ |
| SSE | $[1.0 + 20 \cdot T \cdot (3.0 \cdot \eta - 1)]\, 0.2088$ | $0.6264\, \eta$ | $0.09396 \dfrac{\eta}{T}$ | $0.09396 \dfrac{\eta}{T^2}$ |

Damping correction factor: $\eta = \sqrt{\dfrac{10}{5+\xi}}$ with $\eta \geq 0.55$

Figure 3–2 Vertical OBE and SSE spectra

## 4. CONCLUSIONS

An evaluation of the seismic hazard has been conducted for the site of the new LNG plant in Taranto. The evaluation was carried out using modern zoneless procedures, which do not rely on the construction of seismogenetic provinces of uniform generating capacity. The methodology employed is solidly based from a theoretical standpoint and has been applied by Principia in evaluations of the seismic hazard at all LNG sites in Spain and some abroad.

The studies performed lead to a number of conclusions and recommendations, which are summarily listed below:

a) It is recommended that the following values be adopted for the peak horizontal ground acceleration: 0.29g for the SSE and 0.09g for the OBE.

b) Following the Italian norm OPCM (2003), it is recommended that the following spectra be adopted for design: those in Figure 3–1 for horizontal SSE and OBE and those in Figure 3–2 for vertical SSE and OBE.

## Appendix I. References

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