Seismic Safety of Nuclear Facilities

Italian regulatory practice on design seismic input characterization

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Valuable contribution from our colleague Giovanni Bava is acknowledged

Italian Nuclear Regulatory Authority

- CNEN-DISP 1962 - 1982
- ENEA-DISP 1982 - 1994
- ANPA 1994 - 1999
- APAT 1999 - 2008
- ISPRA 2008 - ……..

Same staff but changed name

- **new!:** ASN (Nuclear Safety Agency) established by law in July 2009 but not yet operative

Earthquakes are parts of natural history and formation of Earth planet.

Scientific investigations followed knowledge development going from ancient mere descriptions of effects to first hypothesis on their origin and, finally, to current advanced seismo-tectonic analyses and debate on earthquake prediction.

The current status-of-art does not give methods to predict when earthquakes will happen, however, what is required by the Regulator is to know with high confidence where an earthquake **might** happen and how large it **might** be (annual frequency of exceedance).

Giannozzo Manetti

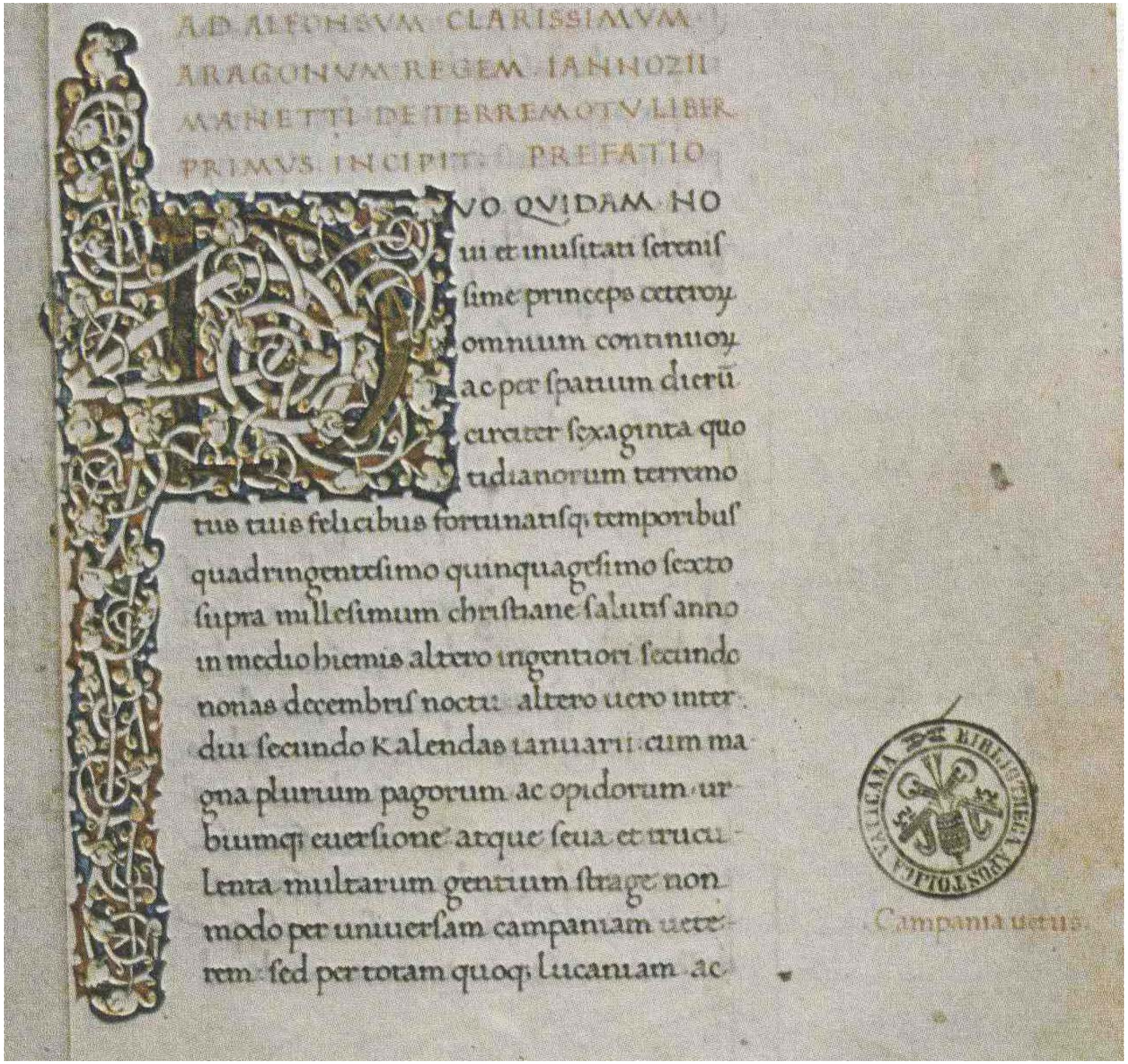
DE TERRAEMOTU,
libri tres

1457-1458

(Biblioteca Apostolica Vaticana)

The most ancient seismic catalogue in the western world.

Italian translation published by ENEA Dec.1983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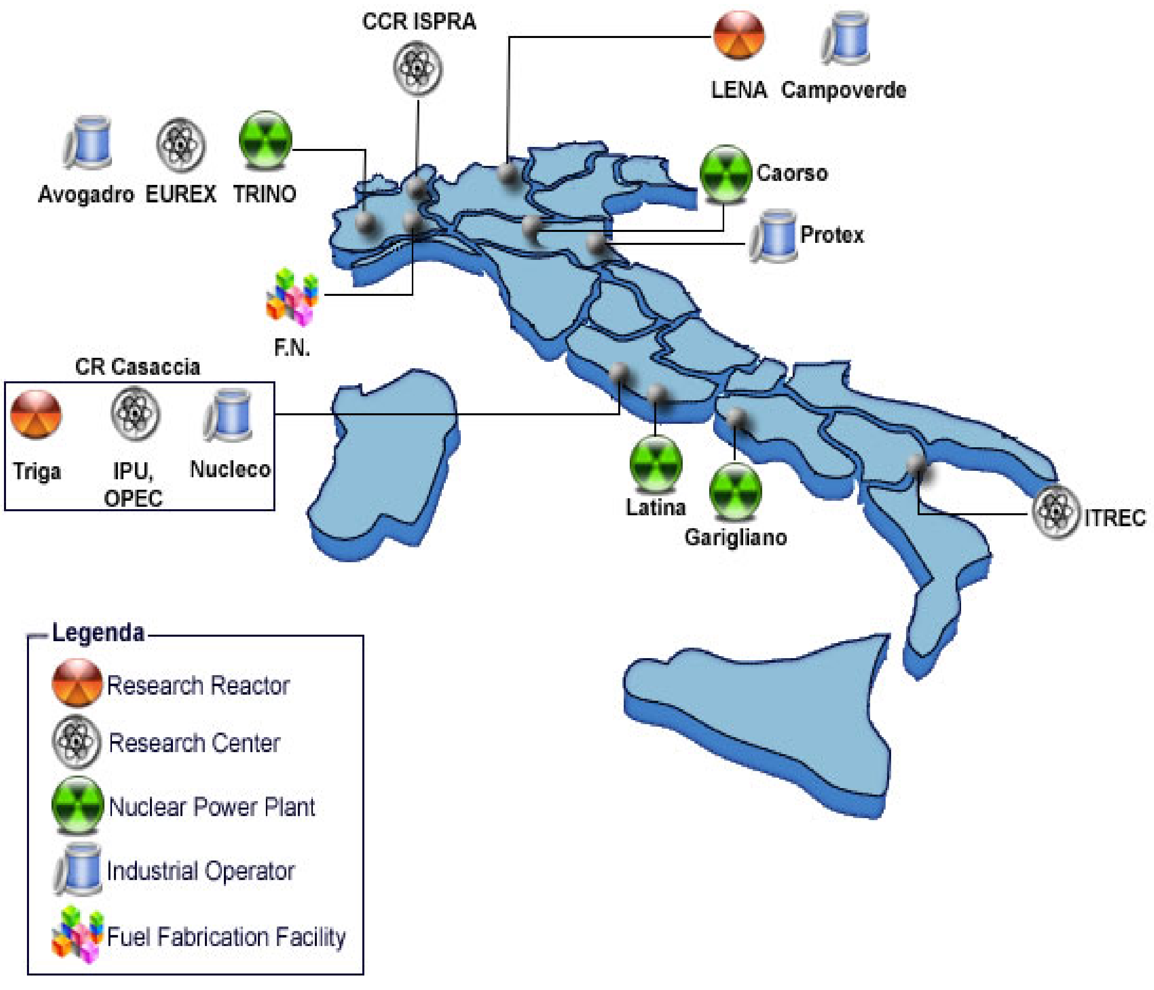
Campania uetus

Nuclear facilities in Italy



PGA values adopted in the past vs. 2008 seismic code

Plant	Type	Power (Mwe)	Operation	Design PGA (g)	Re-Evaluation (g)	2008 Italian seismic code PGA(1)
LATINA	Gas Graphite	200	1963 - 1986	Seismic coefficient 0.07	0,10 minimum	T_{R1000} = 0.084 T_{R2500} = 0.102
GARIGLIANO	BWR Dual-Cycle	150	1963 - 1978	Seismic coefficient 0,07	0.10 – 0.20	T_{R1000} = 0.121 T_{R2500} = 0.156
TRINO	PWR	260	1964 - 1987	Seismic coefficient 0.07	0,10 minimum	T_{R1000} = 0.044 T_{R2500} = 0.053
CAORSO	BWR	860	1978 - 1986	0,24	-	T_{R1000} = 0.112 T_{R2500} = 0.151
ALTO LAZIO	BWR	1000	Construction interrupted 1987	0,18	-	T_{R1000} = 0.075 T_{R2500} = 0.092

(1) Horizontal Peak Ground Acceleration on horizontal rigid soil

PGA values adopted in the past vs. 2008 seismic code

Plant	Type	Power (Mwe)	Operation	Design PGA (g)	Re-Evaluation (g)	2008 Italian seismic code PGA[1]
PEC	FSR	Research reactor	Construction interrupted 1987	0,30	-	TR1000 = 0.25 TR2500 = 0.33
CIRENE	HLWR	Prototype	Construction interrupted 1987	0,19	-	T_{R1000} = 0.084 T_{R2500} = 0.102
ITREC	Fuel reprocessing plant		1962 - 1978	Seismic coefficient 0.07	0.10 – 0.20	T_{R1000} = 0.104 T_{R2500} = 0.130
EUREX	Fuel reprocessing plant		1970 - 1983	Seismic coefficient 0.07	0.10 – 0.20	T_{R1000} = 0.047 T_{R2500} = 0.056

(1) Horizontal Peak Ground Acceleration on horizontal rigid soil

Caorso NPP

- Site analysis: methodology of early ’70ies

- Seismic input characterization
PGA = 0.24g
Design Response Spectra: Plant specific – Housner like

- Design criteria and methods
Dynamic linear analysis
ACI/ASME codes

- Seismic instrumentation

CAORSO NPP
BWR GE 882 Mwe
BWR4 – MARK II – 1977 ÷1986

1980 – 1988: construction of Alto Lazio NPP and issue of technical guide DISP (87) 10 *General Design Criteria for LW NPPs*

- Site analysis

- Exclusion of areas where earthquakes effects > X MCS are estimated from the historical database
- Exclusion of areas with surface faulting
- Regional tectonic regime and potential
- Regional relevant geological structures
- Site neo-tectonics
- Assessment of seismotectonic potential
- Seismic characteristic of potential events
- Reference earthquake

1980 – 1988: construction of Alto Lazio NPP and issue of technical guide DISP (87) 10 *General Design Criteria for LW NPPs*

- Seismic input characteristics for Alto Lazio NPP
PGA = 0.18g free field/bedrock (adoption of minimum value requirement, approximately IX MCS, ignoring site effective lower seismicity)
- Design Response Spectra (broad band): RG 1.60

• Design objective

Safety essential SSC must undergo the design earthquake without damages remaining fully operative.
Safety relevant SSC must undergo the design earthquake without compromising the operation of safety essential SSC.

1980 – 1988: construction of Alto Lazio NPP and issue of the technical guide DISP (87) 10 *General Design Criteria for LW NPPs*

Safety relevant SSC: their failure or malfunctioning can cause accident conditions or significant increase of radiological risk, and those needed to prevent degeneration of abnormal transient plant conditions (reactor isolated cooling system, spent fuel pool ventilation system, general control room supervision and alarm system).

Safety essential SSC: those needed to protect integrity of pressure barrier, perform safe reactor shutdown, operate decay heat removal, prevent significant releases in any accident conditions (primary loops, emergency systems and supporting structures)

In practice, both typologies were assigned to seismic category I.

1980 – 1988: construction of Alto Lazio NPP and issue of the technical guide DISP (87) 10 *General Design Criteria for LW NPPs*

• Design criteria and methods
- ASME and ACI codes, IEEE requirements
- Extreme load combination: Design Earthquake + LOCA
- Linear structural analyses
- Structural demand within the linear field of materials
- Modal damping in soil-structure interaction limited to 10-20% of critical.

This approach is deemed highly conservative and with inherent high confidence of very low probability of core damage in case of seismic event .

Seismic PRA to "measure" the safety level of the plant and the balance of accident sequences should be performed.

1980 – 1988: construction of Alto Lazio NPP and issue of the technical guide DISP (87) 10 *General Design Criteria for LW NPPs*

- In 1987 a technical guide stated the safety probabilistic objectives, which apply also to accident sequences whose initial event is earthquake.
- Their combined annual probability not greater than 10^{-5}.
- To consider feasibility of technical alternatives up to 10^{-6}

The construction program of NPPs was abandoned and planning for decommissioning of dismissed nuclear facilities began to be considered.

Current procedure for seismic design of interim low level radwaste storage facilities and conditioning radwaste facilities

• Scope

Radwaste produced by former plant operation and by decommissioning must be conditioned and safely stored on site until availability of final disposal.

• Seismic input characterization

New Italian structural code for conventional civil constructions in January 2008 which includes a new procedure for seismic input definition and design.

Interim radwaste storage facility

Current procedure for seismic design of interim radwaste storage facilities and conditioning radwaste facilities

- For the limited types of nuclear facilities under consideration, it was decided to endorse this code with specific additional requirements to enhance conservativism for radwaste management and storage.

- PGA values and response spectra shapes are given over a mesh (square 10 km) which covers the Italian territory for period returns ranging from 30 to 2475 years, referred to horizontal rigid soil (uniform hazard spectra).

Current procedure for seismic design of interim radwaste storage facilities and conditioning radwaste facilities

- Seismic input parameters are determined by site geographic coordinates.
- Two period returns are assumed for seismic design: T_{R1} = 1000 years and T_{R2} = 2500 years.
- T_{R1} = 1000 years and design life 50 years correspond to exceedance probability 5%.
- T_{R2} = 2500 years and design life 50 years correspond to exceedance probability 2%.

Current procedure for seismic design of interim radwaste storage facilities and conditioning radwaste facilities

Design structural and systems performance

- T_{R1} = 1000 years : limit damage condition (SLD)

Structural and non-structural members of the construction, relevant systems and equipment must not suffer damages and significant out of service (seismic structural demand not beyond material linearity, seismic qualification of equipment).

Current procedure for seismic design of interim radwaste storage facilities and conditioning radwaste facilities

Design structural and systems performance

- T_{R2} = 2500 years: emergency intervention condition (SLV) Damages of structural members, collapse of non-structural members and out of service of equipment are accepted, but the construction must keep stability and emergency intervention must be practicable for safely construction recovery and radwaste retrievability (limited ductility used by seismic structural demand) .

- Design PGA not below 0.1g

Final remarks

- Seismic input adopted for the oldest plants based on historical database used by construction norms, compared with the new seismic code, show safety levels congruent with requirements then accepted, with the exception of some critical issues of Garigliano

- Seismic input adopted for plants designed in '70ies based also on up to date geological-seismic investigations show to be conservative

- The new Italian seismic code, with additional requirements for enhancing conservativism, provides adequate procedure for design of low level radwaste interim storage and management facilities