The World Major Regulatory Guides For Nuclear Power Plant Seismic Design

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IAEA, USA, ex USSR, Italy, Japan, UK, France and Germany standards used in defining the geologic criteria and seismic parameters in the siting and design of nuclear power plants are analysed in table 1.

Table 1. Standards Considered

IAEA:		Earthquakes and Associated Topics in Relation to Nuclear Power Plant Siting. IAEA Safety Guide, 50-SG-S1, Revision 1, Vienna, 1991.
Italy:	*(a)*	*Informazioni relative alla valutazione della stabilità geologica e geotecnica del sito e dei parametri sismici per la localizzazione e la progettazione delle centrali elettronucleari, ENEA-DISP, Guida Tecnica n° 1, 1993, "Notiziario ENEA-DISP", 1, n. 3, Roma;*
	(b)	*Requisiti e criteri di scelta dei siti suscettibili di insediamento di centrali o impianti nucleari, CNEN, Doc. DISP (77), 2, Roma, luglio 1977.*
Former USSR:	(a)	Provisional Design Standards for Nuclear Power Plants in Seismic Regions. Ministry of Power Engineering and Electrification (MINEHNERGO-URSS), VSN-15-78, 1979;
	(b)	Nuclear Power Standards and Requirements, *ATOMENERGOEXPORT*;
	(c)	Instruction on determining the Composition and the Scope of the Seismological and Seismotectonic Investigations in Designing Nuclear Power Plants and Major Thermal Power Complexes. Ministry of Power Engineering and Electrification, *GLAVNII PROJECT, ATOMTEPLOELECTROPROJECT 1985.*
USA:	a)	Seismic and Geologic Siting Criteria for Nuclear Power Plants. Appendix A of 10 CFR 100, NRC, Washington DC, 1978;
	b)	Criteria for the Seismic and Geologic Siting Criteria for Nuclear Power Plants on or after. Appendix B of 10 CFR 100, NRC, Washington DC, 1992;
	c)	USNRC Regulatory Guides and Standards Review Plans for this issue.
Japan:		Japan Regulatory Guide for Aseismic Design of Nuclear Power Reactor Facilities (revised edition). Nuclear Safety Commission, 1981.
France:		*Règles fundamentales de suretè. Règle N.1.2c, Ministère de l'Industrie de France, Direction de la qualitè et de la securitè industrielles, Paris, 1981.*
Germany:		Safety Standard KTA 2001, (ed 6/90), KTA.
United Kingdom:		Safety assessment principles for Nuclear Plants. HMSO, Health and Safety Executive (HSE), 1992.

Table 2. synthesises the exclusion criteria and minimum requirements described in the standards considered.

Table 2. Exclusion Criteria and Minimum Requirements

Code	Exclusion criteria	Minimum requirements
IAEA	Presence of a capable fault at the site.	Minimum SL2 = 0.1 g anchored to a site specific response spectrum.
Italy	Area of historically observed intensity equal to X MCS (Mercalli-Cancani-Siebergscale)or greater. Presence of a capable fault at the site.	Minimum SEE = 0.18 g anchored to a wide band response spectrum.
former USSR	Sites having a potential for intensity IX MSK (Medvedev-Sponheuer Karnik scale) or greater. In other words: NPP cannot be designed for more than 0.2 g. Presence of a tectonically active fault at the site (capable fault). Zones with strain-rate in the crust, recorded by instruments, equal to or greater than 10^{-5} per year, which corresponds to the relative displacement of the measurement points of 1 mm on a 100 m base.	Bearing capacity of the foundation soil > 0.2 kg/cm^2.
USA		Minimum SEE = 0.1 g anchored to a wide band response spectrum.
Japan	Sites having capable faults or close to faults having a Quaternary slip rate higher than 1mm/year.	Foundation must be on sediments not younger than Tertiary. S2 shall withstand a near field earthquake (minimum distance = 10 km) having M = 6.5.
France		
Germany	Presence of a capable fault at the site.	Minimum peak ground acceleration = 0.005 g.
UK		
USA, France and UK rules do not state explicitly that the site ought to be excluded in the presence of a capable fault; however the normal procedure is to exclude the site.		

Exclusion criteria depend mainly on the availability of suitable sites in a country, sensitivity of the technical and scientific community to the earthquake risk phenomenon and design restrictions for nuclear power plant items. For example, the exclusion criterion of intensity IX or over (MSK) in the former USSR (in other words, nuclear power plants were not designed for a seismic input exceeding 0.2 g) is obviously linked to the large availability of sites and the design restriction for VVER type reactors.

The minimum design basis ground motion at the site may be due either to a near field or to a far field earthquake (or both). In the case of the near field earthquake, this is considered the minimum value of the random (floating) event, which in Japan can be as high as M = 6.5 However, in the Japanese practice, this earthquake is not assumed to be associated with surface faulting on unfaulted Tertiary bedrock.

All standards indicate that the earthquake inside the seismotectonic province of the site, which cannot be related to any structure, should be placed, for conservativism, at a certain depth, under, or very close, to the site. Although such an assumption has no physical basis it is good in terms of cost-benefit analyses when this earthquake is in the range of VII - VIII MSK. or MCS The same assumption is not appropriate when the value reaches IX MSK or MCS because such earthquakes should be always associated to structures detectable with the existing state of the art in geology, geophysics and seismology especially in interplate regions.

For the problem of surface faulting, all standards, with the exception of France, recommend the exclusion of the site more or less explicitly. Surface faulting and/or subordinate rupture depends on the subsurface (structural and rheological) characteristics of the site, on the magnitude (M) and on depth of the earthquake source. For example, as already said, in Japan, it has been assumed that a M = 6.5 earthquake, in their seismotectonic environment, cannot produce surface faulting on unfaulted Tertiary bedrock. Such an assumption, however, in the opinion of the Author, cannot be applied to other areas of the world especially in strike-slip o dip-slip tectonic stress regimes. For example, (Fig. 1, see next page) represents in . a very schematic way, the Author's opinion for the Apennines. Similar models should be done for the various parts of the world.

Regarding the design basis earthquake the existing guides permit it to be calculated in both deterministic and probabilistic ways. Both methodologies need a more or less accurate seismotectonic model of the site region. The consolidated procedure requires that the region of the site to be investigated is 200 miles around the site (this comes from the first USA guide). This value is reasonable for intraplate areas, but it may be excessive in interplate areas where, usually, all the significant seismogenic structures are located in a radius of 100 km, or less from the site.

Regarding the vibratory ground motion it is useful to keep in mind that it has been recognised that NPPs have wide seismic safety margins; that is NPPs can withstand vibratory ground motion much higher than the designed values.

It is very important to point out that in all the guides professional judgement of the experts is significant for evaluation. This judgement can be used in defining the seismotectonic model and in the assessment of the maximum potential earthquake related to structures or provinces. Its quality depends on the professionality of the expert but even more on the reliability of the data-base. It is therefore recommended that the maximum effort should be spent in the accuracy and completeness of such data-base, especially on the more significant data.

In this paper we have not detailed the use of the empirical formulas for calculating the maximum potential earthquakes and for attenuation because the existing literature is so wide that its analysis would require a special paper. However the Author believes that the best method for the solution of these two problems is the comparison with other areas of the world having similar seismotectonic characteristics of the site under consideration (i.e. source geometry, stress regime, rheology).

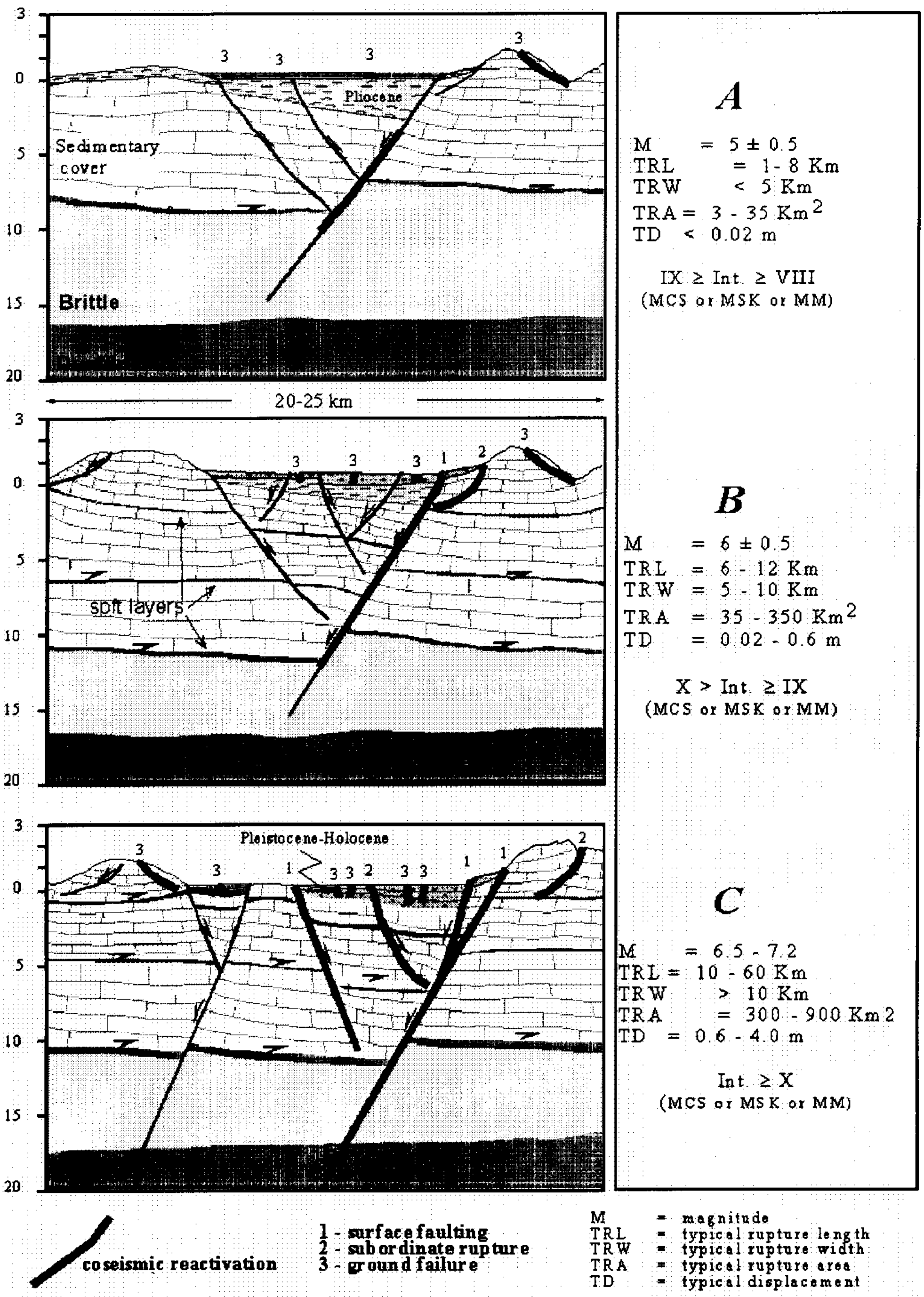

Figure 1.

Surface faulting: fault displacement that mimics the earthquake focal mechanism and is believed to be more (same strike and dip as the main causative fault) or less (branching, splay or antithetic relations with the main causative fault) directly connected to the main causative fault.

Subordinate rupture: any surface rupture having a relationship but not a direct connection with the sieismogenic fault, in other words rupturing occurs on the upward projection of the main causative fault, but is actually driven by slip along a lithologic , and possibly tectonic, boundary. In Italian the Author of this paper uses the term *fraglia* that is the combination of *frana* (landslide) and *faglia* (fault).

Ground failure: all possible non tectonic surface displacements triggered by an earthquake (landslide, including sackung (that can be at the boundary with the subordinate rupture), fractures in soft sediments, liquefactions, jumping of stones, and all the other effects on the ground reported in the Intensity scales (MCS, MSK, MM).