55) ENGINEERING GEOLOGICAL AND SEISMOLOGICAL CRITERIA FOR NUCLEAR POWER PLANT SITE SELECTION AND CLASSIFICATION

SCIENCE GEOLOGIQUE ET CRITERE SISMOGRAPHIQUE POUR LA SELECTION ET CLASSIFICATION DE L'EMPLACEMENT DES CENTRALES NUCLEAIRES

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SYNOPSIS

A procedure based on elementary studies for Nuclear Power Plant site selection and classification is outlined. This procedure is particularly suitable for the early stages of site selection studies especially where a large number of potentially suitable sites have been previously chosen using non-seismic and non-geotechnical criteria. The main influencing factors to be taken into account in this procedure are discussed as well as their relative importance in the selection process.

INTRODUCTION

A recent project undertaken in Spain involved the seismotectonic and engineering geological classification and ranking of a large number of possible nuclear power station sites. These sites had previously been chosen using topographic, hydrological and demographic criteria and it was the aim of the studies outlined in this paper to further evaluate and rank the chosen sites, taking into account both seismicity and engineering geological factors.

Due to the wide geographic distribution of the sites and the limited time available for study it was necessary to use fairly coarse screening techniques to select and rank sites, leaving site investigation sensu strictu for the prime sites that emerged from these studies. A methodology was established which required synthesis of geological, tectonic and seismic information in the formulation of a relatively coarse site classification procedure. The procedure took into account the general approaches adopted by the United States Regulatory Commission (USNRC) and the International Atomic Energy Agency (IAEA) but did not cover all the requirements of the USNRC. It was considered that sites emerging from the classification scheme with few penalties were more likely to comply with the site licensing recommendations of the USNRC than those with a greater number of penalties. For the purposes of this study potentially active faults were tentatively defined as those faults, or members of a set of faults, which showed evidence of post-Miocene or Quaternary displacement and/or passed within the accepted limits of location of an earthquake epicentre, as defined by Munuera 1963. The term "capable fault" as described by USNRC was purposely avoided, as its use requires more detailed studies and site investigations than those which could be carried out in these early stages of the project.

To make it easier to satisfy possible future licensing requirements with respect to faults the term "clear areas" was introduced to indicate those areas which were at least 8 km from a "major" active fault, or at least 5 km from any known smaller active fault. These distances were somewhat arbitrary, but chosen with USNRC requirements in mind.

The geological work was based on a preliminary desk-study with revision of the literature dealing with the tectonic and neotectonic aspects of the Iberian Peninsula, analysis of geological maps mainly at 1/200.000 and 1/50.000 scales and Landsat imagery studies at 1/200.000 and 1/500.000 scales to assist in the identification of active faults. Topographic and bathymetric maps aided the correlation of crustal "accidents" with topographic and morphological features. The seismological work was based on lists of earthquakes assembled from various sources (Munuera - 1963, the National Oceanic and Atmospheric Administration in the USA, - the Global Seismological Unit in Scotland and the International Seismological Centre in England). A published assessment of the accuracy of epicentral location was used to assist in assigning earthquakes to particular faults (Munuera 1963). Intensities (Modified Mercalli, MMI) were used for seismotectonic analysis rather than magnitudes because it was found that historical records of MMI from Spanish sources were more homogeneous than the available lists of earthquake magnitudes.

Seismotectonic studies used the so-called deterministic and probabilistic methods of analysis. The deterministic maximum local intensity was obtained by assigning the maximum historical intensity ascribed to a seismotectonic province to the nearest major active fault and then reducing it by an attenuation law proportional to distance and the focal depth of the earthquake (Munoz et al 1974, Shukla et al 1977). The probabilistic studies gave return periods for the maximum local intensity as if it was part of the "background" seismicity (Cornell 1968, Merz and Cornell 1973). The correlation of epicentres with faulting had enabled the preliminary identification of a number of seismotectonic provinces, with line- and point-sources of earthquake activity. This information was used together with redefined and confirmed seismotectonic zones (Soriano et al 1976) to provide both probabilistic and deterministic assessment of the expected intensity at each site or group of sites. The deterministic intensity and the intensity at long return periods used in these cases were for site ranking and comparison purposes only. Short visits were made to site areas in order to make preliminary engineering geological assessments.

INFLUENCING FACTORS

The main factors that were considered likely to influence siting were classified into three categories: critical factors, seismotectonic factors and geotechnical factors.

Critical Factors were defined as those more obvious factors that, if present, would render a site totally unsatisfactory from a siting or licensing viewpoint. They are "exclusionary criteria" and defined as follows:

Non-geological factors such as demographic, topographic and hydrological considerations.
Active faults on site or within the previously mentioned distance limits.
Recent or Quaternary volcanism on or near the site area.
Deep-seated ground instability.

Seismotectonic Factors The deterministic and probabilistic analyses gave an indication of the earthquake intensities and their return periods to be expected at positions that were considered representative of sites within given areas. These quantities were used in a relative manner to provide comparisons between different site areas and to enable sites to be ranked in an elementary but useful grading scheme. In addition to the seismicity study the following closely related factors were taken into account:

The distance from the site to the nearest known or suspected active fault.
The distance from the site to inactive faults.
The quality of the seismic and tectonic input information.

This scheme allowed classification into four groups:

A - Minimal seismic problems; nominal study required to establish the Safe Shutdown Earthquake (SSE) and to satisfy other licensing requirements.

B - Slight seismotectonic problems; moderate study required to establish a SSE and to check distance to major faults that could be considered capable by USNRC definition.

C - Significant seismotectonic problems; detailed study required to establish a SSE and to avoid capable faults believed to be close to the site.

D - Severe seismotectonic problems; intensive study required to establish a SSE and to search for capable faults which are likely to exist very close to or on the site.

In addition to the factors already listed it was necessary to take account of any information that was available on non-seismogenetic faults such as those showing signs of creep movements or post-Miocene and Quaternary fault movements not known to be associated with any recorded earthquakes. Indirect risks from seismic shock had to be considered, such as tsunami, slope failure, liquefaction and ground failure resulting from seismicity -induced collapse of natural underground cavities and weak soils.

Geotechnical Factors included those engineering geological factors with a direct relationship with the foundations and earth works. The main factors taken into account were:

Depth of the bearing stratum as a preliminary evaluation of the type of the foundation required.

Slope instability problems

Presence of solution cavities that could require ground stabilisation

Active erosion or sedimentation problems

Unfavourable topographic conditions that could need excavation or filling, with special reference to the need to use explosives for excavation

Quality of the engineering geological information used.

The geotechnical factors would, at this stage, exercise much less influence on the licensing requirements than the seismotectonic factors, unless obvious major ground problems were present.

The so-called "clear areas" were found to contain 10% of the total potential sites, and these were allocated to appropriate sections of the four main seismotectonic classifications. Because of the imperfect screening process it was recognised that many of the remaining sites could be still acceptable after subjection to more detailed on-site investigations of faulting. The sites in the "clear" areas were considered to offer the best chance of satisfying licensing requirements, but it was also thought necessary to rank the remainder of the sites using a penalty-points grading system. Thus, some of the more favoured sites in, as it were, the "second division", could approach the less favoured sites in the "first division", and if eventually detailed investigation showed that any were clear from a seismotectonic point of view their rating would rank them with the more favoured sites.

In the example undertaken in Spain the value of a site was assessed by a marking system. Critical factors were given the highest points. The seismotectonic classes already mentioned were evaluated according to a range of points, for example Class A = 0 to 50, B = 50 to 100, C = 100 to 150, D = greater than 150. The main criteria used to achieve these values were:

Faulting Points were allocated depending on the number of active faults within 10 km of each site, the distance to intersections of two or more active faults and similarly for faults considered to be inactive (with a correspondingly much-reduced penalty allocation)

Earthquake intensity The maximum earthquake intensity expected at a site influenced the allocation of penalty points for each site. Probabilistic analysis gave maximum local intensities with their respective return periods within the range 100 to 10^6 years.

Quality of information The quality of the seismotectonic information was assessed and allocated penalty points where necessary.

CONCLUSIONS

The procedure outlined in this paper has proved to be of great assistance during the earlier stages of nuclear power plant site selection; it can be carried out in a reasonable period of time using fairly unsophisticated techniques. The limitations of the scheme are fully appreciated and many have already been minimised in later stages of the work. It has proved particularly useful where a great number of apparently suitable sites have to be evaluated from a seismic and geological view-point. The procedure can also pave the way to the planning of future investigations with a better understanding of the engineering geological and seismological conditions of particular sites.

The influence factors considered in this paper as critical are mainly exclusionary criteria and are closely related with the security and safety of the plant. The seismotectonic factors play an essential role in both the security and safety of the plant as well as an important influence on the economy of the plant. The geotechnical factors represent a less important criteria for this preliminary stage of site selection, unless a very important geotechnical problem is seen to be present. It would be very useful for site selection and ranking purposes to more clearly relate the implication of the influence factors herein considered on the total cost of the plant because the cost is a sensitive and measured parameter, even in a rough estimation and for preliminary evaluations.

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