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SEISMIC DESIGN OF A BUILDING CONTAINING LIMITED RADIOACTIVE INVENTORY

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ABSTRACT

The description of the seismic analysis and design of a building containing limited radioactive inventory, to be constructed in Brazil, is presented in this paper. The design guidelines to be adopted, including standards to be followed and methods of seismic analysis to be used, are discussed. The carried out seismological analysis of the site is presented, as well as the description of the bulding and of the corresponding tridimensional structural model; main results of the seismic analysis are presented and discussed in the paper.

1. INTRODUCTION

The design of facilities with small radioactive inventory has been traditionally performed following usual criteria for industrial buildings. Nevertheless, in the last few years, more stringent criteria have been adopted in new nuclear facilities, in order to achieve higher standards of environmental protection.

In a uranium conversion plant, presently under construction in Brazil, special seismic criteria were defined for the design of the UF_6 (uranium hexafluoride) production building, due to the potential of radioactivity release to the environment in the operations performed within the building. Adopted design criteria and details of the seismic design of the UF_6 building are presented in the following.

2. SEISMIC DESIGN CRITERIA

In uranium conversion plants, the UF_6 production step is the part of the process with the highest potential of radioactivity release, because of the operations performed in the UF_6 desublimers and cylinders filling areas, and also in the UF_6 distillation facilities, when present in the building, due to process requirement.

For defining the seismic design criteria, it was decided to follow the Basic Standards for Radiation Protection, IAEA Safety Series no. 9 (1982). According to these standards, non-stochastic effects to individuals are prevented if the annual dose equivalent to any organ does not exceed 0.05 Sv; collective dose equivalent shall not exceed a few person-sieverts. To assure conservatively the fulfilment of the IAEA criteria, it was decided to contain any UF_6 release inside the building, during normal and emergency conditions, as well as after a seismic event. Fig. 1 depicts a schematic longitudinal building section.

General criteria for the design of the plant were already discussed by Bragança Jr. et al. (1992). Plant items are classified according to their required resistance with respect to a design basis earthquake. Structures, equipment, and systems are divided in three categories, namely:

- Category I: items for which seismic requirements are defined in order to preserve containment.
- Category II: items for which seismic requirements are defined only to avoid damage for items of Category I.
- Category III: items for which failure will not affect safety, and for which no special seismic requirements are defined.

The main building structure is classified as Category II, and structural integrity will be required during seismic events. In the critical areas of the building (cylinder filling station and desublimers) radioactive leakage is prevented using equipment and isolating valves as a primary barrier. During a seismic event, these valves, actuated by acceleration sensors, will close down immediately, isolating these critical process areas from the remaining ones.

The desublimers will be physically protected against internal missiles generated during the design earthquake event, such as heavy loads dropping from cranes, by missile impact barriers. In addition, in the most critical building area (cylinder filling station), a concrete structure classified as Category I is designed for containing any eventual release of UF_6, even during a severe seismic event.

3. ANALYSIS OF THE SEISMOLOGICAL CONDITIONS

Since the design and construction of the first Brazilian nuclear power plant, in Angra dos Reis (Units I and II), several seismological studies have been done in Brazil, regarding mainly the Brazilian Southeast Region; for instance, Assumpção (1983). From this study, Fig. 2 shows the recurrence period for earthquakes of several magnitudes, in Brazilian Southeast. Maximum horizontal ground accelerations can be evaluated as a function of the magnitudes and focal distances through attenuation functions. The expressions proposed by Donovan (1973) and Esteva et al. (1973) for attenuation are graphically displayed in Fig. 3 for magnitudes 5,6 and 7.

A comprehensive seismological analysis, specific for the site, was done. According to general Brazilian Southeast Region conditions, the foreseeable seismic activity in the site is very low. Maximum recorded historical intensity, within a radius of about 200 kilometers was found to be inferior to VII (Modified Mercalli). Then, a maximum soil acceleration of 0.1g was conservatively adopted, for the maximum credible earthquake. It is to be observed, from Fig. 2, that the recurrence period, in

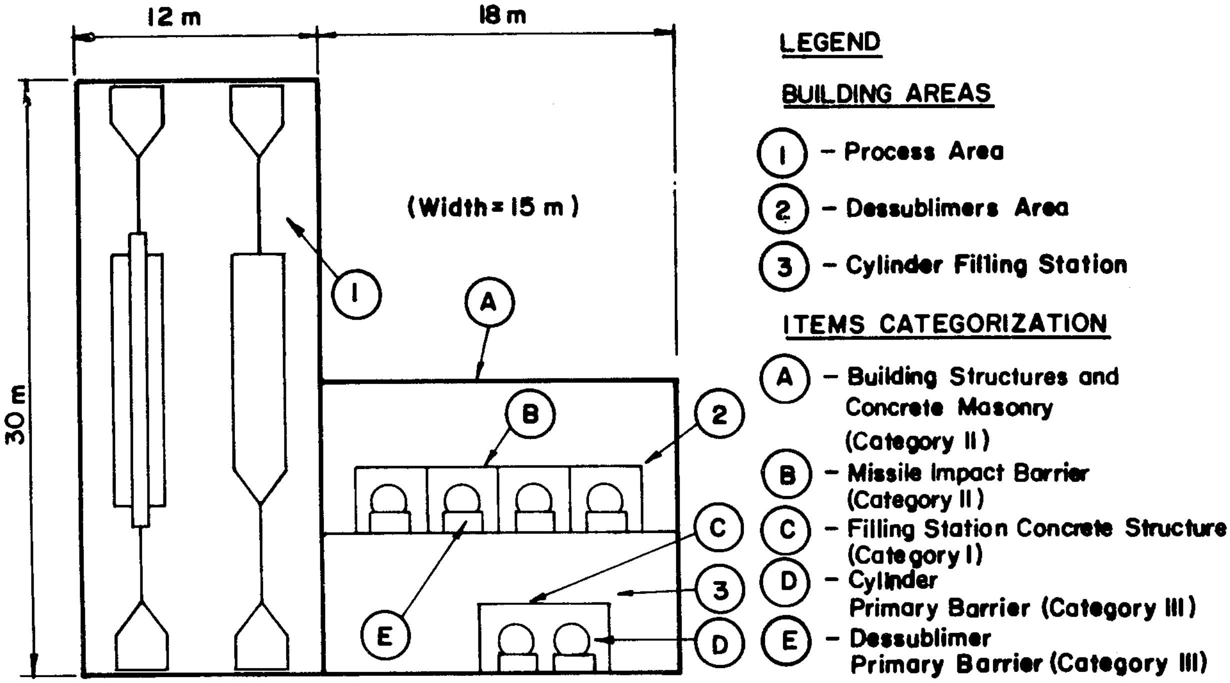

FIG. 1

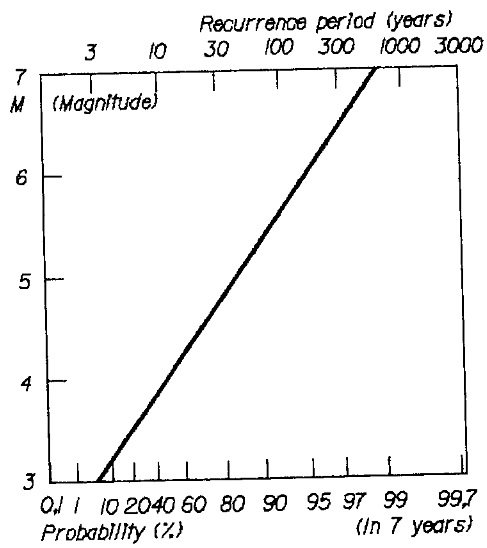

Fig. 2

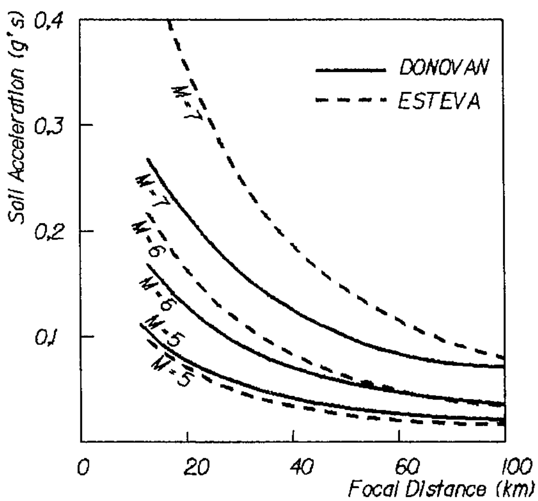

Fig. 3

Southeast Region, for magnitude 7 is about 600 years. From Fig. 3, it can be seen that for magnitude 7, the acceleration of 0.1g will be adequate for focal distances above 80 km; since no active faults were found in the vicinity of the site, the adopted acceleration will be conservative.

4. SEISMIC ANALYSIS AND DESIGN OF THE BUILDING

In the absence of a national standard regulating the design under seismic conditions, it was discussed the possibility for applying three different approaches for the design of the UF_6 building, corresponding to three different design codes, which are listed below, in crescent order of conservatism:

- Uniform Building Code (UBC), (1982)
- Earthquake Resistant Design of Nuclear Facilities with Limited Radioactive Inventory (IAEA - TECDOC-348), (1985).
- IAEA Safety Guides for Nuclear Power Plants, nos. 50-SG-S1 and 50-SG-S2 (1979).

4.1 Uniform Building Code (UBC)

UBC has been used in USA and other countries for the seismic design of usual industrial buildings. A total static equivalent seismic force is defined by equation (12-1) of the code:

V = ZIKCSW (W - total dead load)

The following numerical values were considered in this analysis: Z = 3/16 (Zone 1), I = 1.5, K = 0.67, C = 0.08 (T = 0.7s), S = 1.5. Total static equivalent force is distributed over the height of the structure according to equation (12-5) of the code:

$Fx = V.W_x.h_x/\Sigma w_i h_i$ (w,h - dead load and height of each floor).

4.2 IAEA - TECDOC - 348

The building can be classified as Class B according to this code (structure shall not colapse, containment shall preserve leak tightness). Then, the Equivalent Static Approach may be used; horizontal forces over the height of the building are given by equation (7.1) of the code:

$F_i = a_g. Csi. W_i$ (W_i - dead load of each floor)

Considered numerical values: $a_g = \gamma \, . \, a_b$; $\gamma = 1.0$ (firm bearing strata); $a_b = 0.08$ g (Imax = VII Modified Mercalli); Csi = Si ($\mu = 1.0$, ductility, Class I structure), varying between 1.0 (ground level), 1.5 (gravity level of the building) and 2.25 (top of the building); amplification of the accelerations along the height of the building is, in this way, considered approximately.

4.3 Safety Guides 50-SG-S1/S2

A dynamic analysis of the building, using an enhanced version of the SAP IV computer program, was done. For this, the building was modeled as a tridimensional space frame, with 224 nodal points, 481 beams, and 1122 degrees of freedom, as shown in Fig. 4. The analysis was done for the standard design response spectra defined in IAEA 50-SG-S2, adapted for the horizontal ground acceleration of 0.1 g (IAEA S2 intensity level).

The generation of artificial time-histories, matching the defined response spectra, was done using PROMON´s GERA program. Seismic soil amplification was analyzed using the SHAKE program, and was found to be very small in the given soil conditions (3m of firm residual soil over weathered rock).

4.4 Main Results of the Analysis

The horizontal (equivalent) accelerations profile over the height of the building is shown in Fig. 5, determined according to the three described procedures.

The third approach is clearly, in this case, the most conservative one. An "average" horizontal acceleration was also determined (total horizontal seismic force/total dead load), giving: 0.023 g (UBC), 0.125 g (TECDOC) and 0.232 g (50-SG).

Final design of the building was done according to the criteria of IAEA Safety Guides 50-SG-S1/S2. Structural elements were designed for critical combinations of static and seismic internal forces.

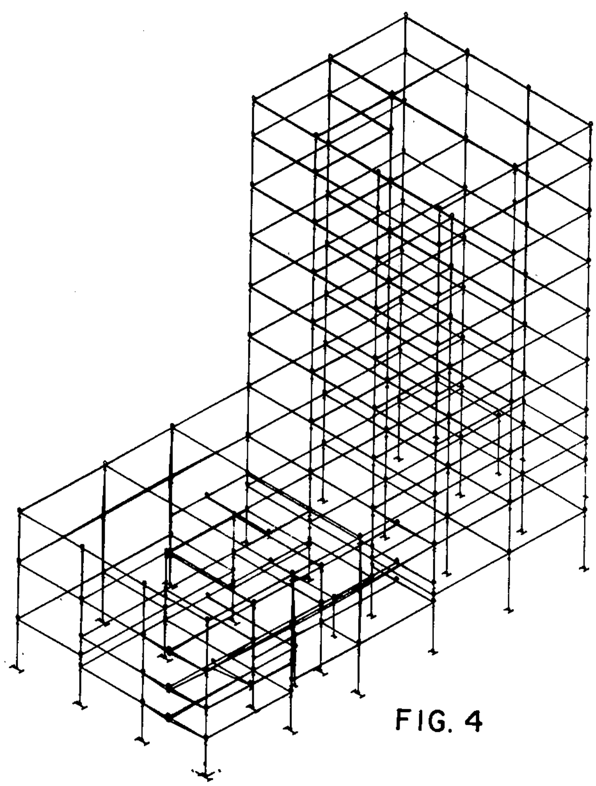

FIG. 4

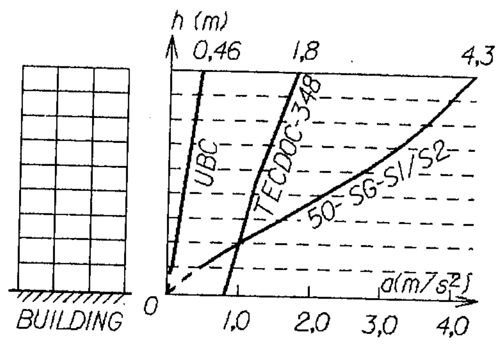

Fig.5 - ACCELERATIONS OVER THE HEIGHT OF THE BUILDING

5. CONCLUSIONS

A UF_6 production building is being designed according to very stringent criteria, despite its small radioactive inventory, even considering that less rigorous criteria could be eventually defensible before the Brazilian licensing body. The considered criteria, using a complete dynamic analysis of the building, lead to more precise and conservative results: actual dynamic characteristics of the building are accordingly taken into account.

An economical analysis was done, showing that total plant costs are increased in less than 3% using the defined seismic resistant criteria, with respect to a conventional plant design. It was considered that additional costs are largely compensated for by the higher levels of environmental, plant personnel and members of the public protection to be achieved.

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