A unified approach for the seismic design of 500 MWe pressurized heavy water reactor buildings

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ABSTRACT

India is planning to increase its nuclear capacity by constructing a number of small size (235 MWe) and large size (500 MWe) pressurised heavy water reactors (PHWRs). To enable the construction of a series of power reactors of standardised design at various rocky sites under consideration, an enveloping ground motion has been generated which takes care of the local seismic conditions at these sites. Seismic analysis of a typical 500 MWe PHWR building has been carried out for local site conditions as well as for the enveloping ground motion. The paper presents the approach adopted for developing standard earthquake design for 500 MWe nuclear power plants. Various features of modelling are also described in this paper.

1 INTRODUCTION

It is a well established fact that the analytical process for the seismic design of nuclear power plants is not only complex but also time consuming. In most of the cases, this forms a substantial part of the entire design package. Designs based on local site conditions, therefore prove to be uneconomical in view of the change in design parameters for each site. This affects the structural design as well as equipment design which are required to be different for each site depending upon seismicity of the site. Thus seismic qualification of the reactor building, other structures and equipments become as essential part of this exercise.

It has been a realised fact that where a large Nuclear Power Programme is contemplated the standardised design is desirable as it is not only economical but also helps speedy execution. There are two ways to have standardised design. (i) By using base isolation system (ii)by using standardised ground motion. Base isolation system has shown its utility in moderately seismic zones having rocky terrain. However, for foundation conditions, with alluvial soils its application has limitations. Some countries have chosen two ground motions; one for rocky sites and one for soft sites. In the

PHWRs used in India the use of base isolation has been presently found not suitable due to large embedments of the structure below the ground. An approach to use standard ground motion for similar sites found its immediate suitability. This approach is also free from probable extra financial burden arising out of special base isolation system.

India is planning to enhance its nuclear capability by installing a number of larze size (500 MWe) units. For the various rocky sites under consideration at present, a standard ground motion called the enveloping ground motion hasbeen evolved for the use in design. In order to illustrate the efficacy of this design, limited analysis (i.e. response spectrum analysis) was carried out for local site conditions as well as for the enveloping ground motion.

2 EVOLUTION OF STANDARD GROUND MOTION

A seismic study of various rocky sites under consideration was undertaken and parameters like magnitude of earthquake zero period acceleration (ZPA) and local site spectra were generated for each site. These parameters have been evaluated for each site on the basis of geological set-up and seismotectonic studies. The site dependent parameters for safe shutdown earthquake (SSE) are as follows (Ref.4):

Site	Earthquake Magnitude	ZPA
1	5.0	0.1 g
2	6.5	0.2 g
3	6.5	0.2 g

The ground motion response spectra for these sites are as shown in Fig.1.0. It can be observed from this figure that these three sites can be brought under a common spectrum called the enveloping spectrum. This enveloping spectrum has been then used for the standard seismic design for all the three sites. The same design can be adopted for a new future site with similar local soil conditions and having the site dependent spectrum below the enveloping spectrum. Thus it will tremendously cut down the design efforts, cost and time.

3 SEISMIC ANALYSIS OF REACTOR BUILDING

The reactor building consists of various sub-structures like inner and outer containment, calandria vault and internal structures all resting on a massive circular raft (Fig.2.0). The analysis has been carried out by modelling the individual sub-structures as massless cantilevers of appropriate stiffnesses with masses attached to various nodes. Separate models have been considered for the two mutually perpendicular (N-S and E-W) horizontal directions and one vertical direction.

Salient features of the mathematical, model include evaluation of geometrical properties of various sub-structures, effect of flexibility of floors and domes for vibrations in vertical direction, and the effect of foundation conditions and side fill on the superstructure.

Whereas the evaluation of geometrical properties like shear areas and moment of inertia is simple for inner and outer containments, it requires a detailed investigation to find these properties for internal structures and calandria vault. A 3-D FEM analysis as well as experimental work using a 1:100 aluminium model was done to arrive at suitable properties (Ref.1.0).

The effect of foundation conditions and the side fill on the super-structure was simulated by introducing equivalent soil springs on the basis of half space theory (Ref.2). Response spectrum analysis of the reactor building was carried out for various site dependent response spectra as well as for the enveloping spectrum using computer code SAP-IV (Ref.3). Table 1.0 shows the frequencies and modal participation factor for the first six modes of vibration. For the sake of comparison the response of reactor building for N-S vibration only is reported here. Tables 2.0, 3.0 & 4.0 respectively show the comparison of SRSS displacements, shear forces and bending moments at salient points.

4 CONCLUSIONS

A closer look at Tables 2.0, 3.0 & 4.0 reveals that the response predicted for enveloping grounds motion encompasses the individual site responses. This proves the adequacy of the standard design adopted. The design based on enveloping ground motion can therefore be adopted at any one of these sites. This will not only cut down the cost and time required for design and analysis of reactor building but also results in the standardisation of equipments and structures, thereby saving considerable time in the procurement of equipments and other structural materials. However, a real cost-benefit analysis can be realised only if the additional pay-off to be spent against the building and equipments design (using enveloping ground motion instead of local site dependent spectrum) is weighed against the cost reduction resulting out of standardisation. Nevertheless the standard ground motion design philosophy is gaining greater importance because of its viability where seismic isolations cannot be easily used.

REFERENCES

Soni R.S., Remireddy G, Kushwaha H.S, Kakodkar A, et.al. Seismic Analysis of 500 MWe PHWR Building under horizontal & vertical ground motions, BARC internal report.

Whitman R.V, Soil Structure interaction,

R.J.Hansen, Seismic Design of Nuclear Power Plants. MIT Press

Bathe & Wilson, SAP-IV Structural Analysis programme-IV.

Kulkarni N.N, Goray J.S, Soni R.S, Kushwaha H.S. Standard earthquake resistant design for 500 MWe Nuclear Power Plants 8th Int.Symp.on Earthquake Engg.,Dec.29-31, 1986.

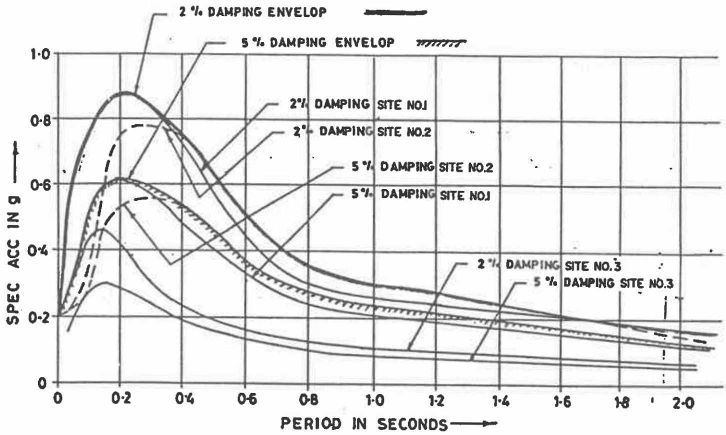

FIG NO.1

ACCELERATION SPECTRA FOR SAFE SHUTDOWN EARTHQUAKE
FOR SITE No. 1, 2 & 3
ALONG WITH ENVELOP SPECTRA

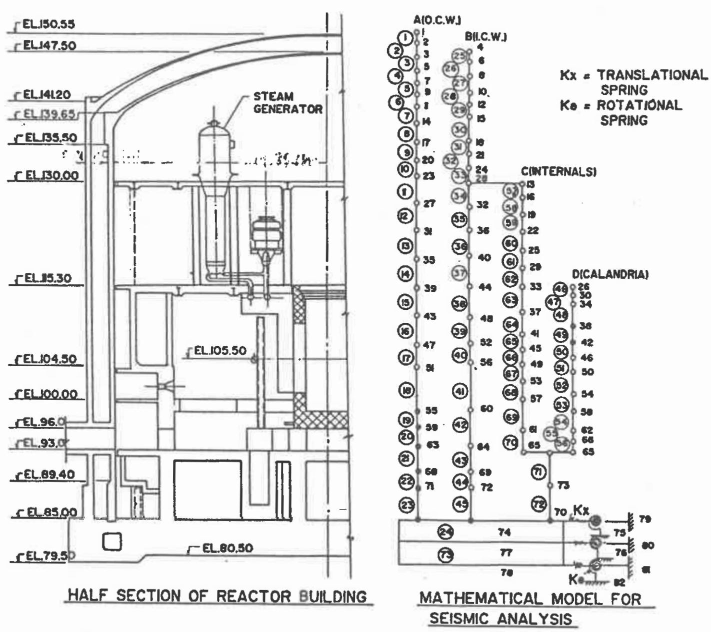

Fig. 2 MATHEMATICAL MODEL OF REACTOR BUILDING FOR ROCKY SITE (N-S & E-W)

TABLE 1.0 : Time Periods (T) and Mode Participation factors (Cr) for the first six modes of Vibration

Mode	N - S		E - W		Vertical	
	T(Sec.)	Cr	T(Sec.)	Cr	T(Sec.)	Cr
1.	0.2525	1.71	0.2654	1.706	0.0914	1.57
2.	0.199	1.271	0.1984	1.193	0.075	0.006
3.	0.1625	0.877	0.1419	0.593	0.0733	0.11
4.	0.1378	0.714	0.112	1.25	0.0438	1.09
5.	0.0925	0.586	0.080	0.85	0.033	0.89
6.	0.081	0.405	0.074	0.102	0.028	0.41

Table 2.0 : Comparison of SRSS displacements (mm) for vibration in N - S direction.

Mode No.	Site No.1	Site No.2	Site No.3	Standard
1.	3.2	6.6	7.2	7.4
4.	5.4	13.1	14.1	14.6
13	4.4	10.7	11.5	11.9
26	2.0	3.3	4.2	4.2
74	0.11	0.25	0.282	0.287

Table 3.0 : Comparison of SRSS shear forces (ton) for vibration in N - S direction

Element No.	Site No.1	Site No.2	Site No.3	Standard
23	2776	5645	6372	6313
45	4147	10070	10830	11190
56	1198	1817	2428	2370
70	4774	8349	10330	10210
73	8418	18120	20360	20700

Table 4.0 : Comparison of SRSS Bending Moments (t-m) for vibration in N-S direction.

Element No.	Site No.1	Site No.2	Site No.3	Standard
23	133500	271200	306300	303400
45	194900	471700	507900	524400
56	18730	27850	37640	36620
70	82930	180200	202000	206000
73	349300	824800	894500	919700