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DYNAMIC ANALYSIS OF PRESSURISED HEAVY WATER REACTORS

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ABSTRACT: Water Reactors are nuclear power plants which use water to control and remove the heat from the nuclear fuel in order to convert heat to electricity. In this report, we have considered the number of nuclear reactors and their locations in our country. Among all those nuclear reactors, we have selected the nearest kalpakkam reactor which is located in Chennai, India. All the faults, around 500 kms from the reactor are considered. From the past history of earthquake data (1812-2002), the maximum magnitude of each fault and source parameters for some faults has been determined. The soil liquefaction characteristics of a site and the procedure for generating Synthetic accelerogram using the Stochastic Method Simulation of ground motion from earthquakes (SMSIM) have been discussed. For performance evaluation, a 3-dimensional model of the dome was taken and dynamic analysis (Time History analysis) was performed to evaluate the displacements at each floors. The 3-dimensional model of the dome was modeled in computer program SAP2000 and Dynamic (time history) analysis was performed on the structure to evaluate the structure's response. The model was analyzed for the earthquake ground motion obtained from SMSIM.

KEY WORDS: Reactor, Earthquake, Magnitude, Faults, Ground motion.

INTRODUCTION

The first stage of the Indian nuclear power programme is based on utilization of natural uranium resources available in the country for a series of reactors known as pressurized heavy water reactors (PHWRs). First of these reactors were of 220 MWe capacity, the technology for which was indigenized and standardized. The efforts in furthering this technology are continued for evolving the design of a 700 MWe pressurized heavy water reactor.

PRESSURISED HEAVY WATER REACTORS

The pressurized heavy water reactor is a horizontal pressure tube reactor using natural uranium dioxide fuel with heavy water as moderator and coolant. The moderator is at low-pressure and temperature. The coolant is maintained in single phase by pressurization. Heat extracted by the coolant from the fuel is transferred to the secondary side light water to produce steam. Figure1 shows the typical schematic flow diagram of a pressurized heavy water reactor.

The power output is enhanced by utilizing margin in the fuel linear heat rating and further flux flattening. Extraction of additional heat is achieved by allowing boiling of coolant near the channel exit. Thus, it is seen that the same reactor assembly and the same primary coolant loop are capable of delivering thermal energy equivalent to 700 MWe output resulting in a significant economic advantage. In a pressurized water reactor, the water is under enormous pressure so it can't boil. Instead, it's pumped to a heat exchanger outside the reactor. This heat exchanger transfers heat to water in another pipe, which boils to create the high-pressure steam that drives a generator.

PWRs are used for marine propulsion in aircraft carriers, nuclear submarines and ice breakers. They are popular in several countries because they use less expensive natural (not enriched) uranium fuels and can be built and operated at competitive costs. The continuous refueling process used in PHWRs has raised some proliferation concerns because it is difficult for international inspectors to monitor. PHWRs, like most reactors, can use fuel other than uranium.

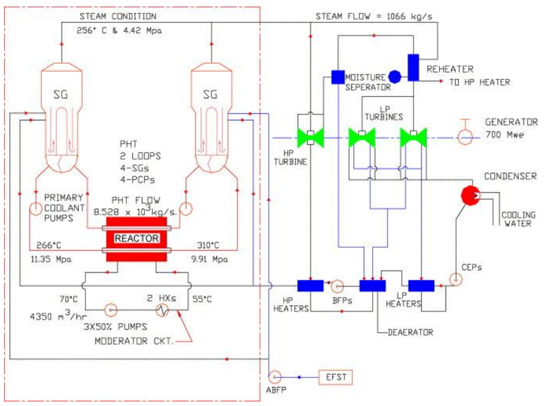

Fig.1 Typical schematic flow diagram of a pressurised heavy water reactor

LOCATING THE REACTOR AND THE FAULTS

Nuclear reactors in our country are located at Chennai, Kalga, Tarapur, kakrpar, Rajasthan, Narora, Chasnupp and Kanupp. Among all these nuclear reactors, kalpakkam reactor is considered which is located in Chennai at latitude of 12.57 & longitude of 80.12. All the faults, around 500kms from the reactor are considered, using the Seismotectonic map details & faults had been located using open jump software. From the past history of earthquake data (1812-2002), the magnitude of each fault is considered. Figure 2 shows the location of the kalpakkam and the faults.

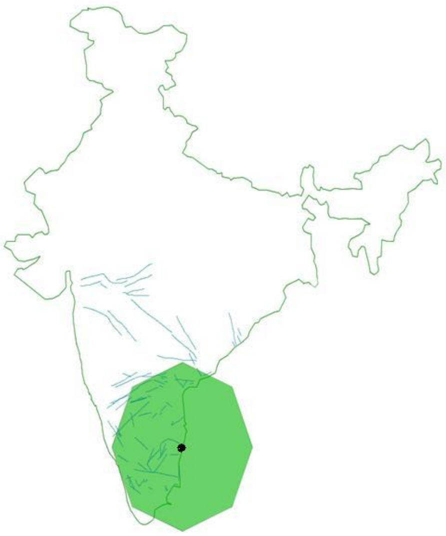

Fig.2 shows the location of the kalpakkam and the faults

CALCULATING THE RETURN PERIOD

For the calculation of cumulative damage due to various seismic events at the reactor, it is necessary to know the number of events of different magnitudes occurring in a given time. For this, we need to know the rates of occurrences of the earthquakes of different magnitudes for each contributing source.

The average rate of occurrence per year n_{lk} of magnitude, M_k earthquakes at the l^{th} source may be obtained by using the following relationship given by Gutenberg and Richter (1942) mentioned in Eq. (1).

$$logn_{lk} = a - bM_k \quad (1)$$

here a, b are constants estimated from data of past earthquake records, $1/n_{lk}$ would represent the mean return period of the occurrence for M_k magnitude earthquake's at the l^{th} source.

The estimation of seismicity parameters based on completeness criteria for 1842-2002 is shown in Figure 3. The highest magnitude of each fault, and return period is calculated using the Gutenberg and Richter (1942).The fault length, focal depth, strike of fault and dip of fault and the highest magnitude are determined from the Seismic atlas of India for some of the major faults.

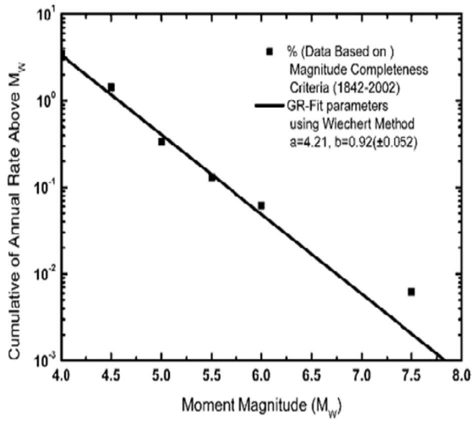

Fig.3 Estimation of seismicity parameters based on completeness criteria for 1842-2002

Using the parameters obtained and assuming constant values, and by using the stochastic model simulation or strong motion simulation (SMSIM), twenty synthetic accelerograms were obtained. Figure 4 shows the plot of peak ground acceleration at the respective time intervals for one acelerogram. The maximum peak ground acceleration obtained from the graph is 0.753 m/ sec^2.Figure 5 shows the plot of peak ground velocity, which is obtained by integrating the acceleration values. The maximum peak ground velocity obtained from the plot is 1.49 m/sec. Figure 6 shows the plot of peak ground displacement and the maximum peak ground displacement obtained from the plot is 6.05m.

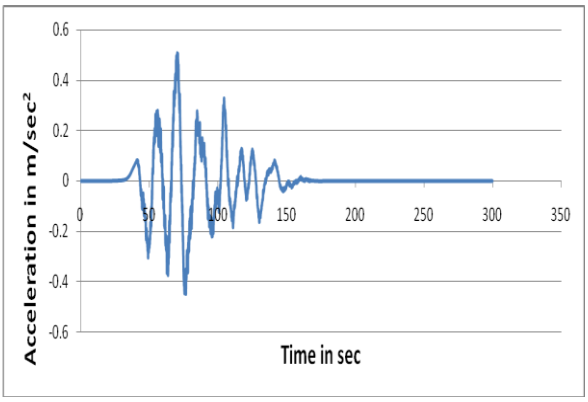

Fig.4 shows the plot of peak ground acceleration vs time

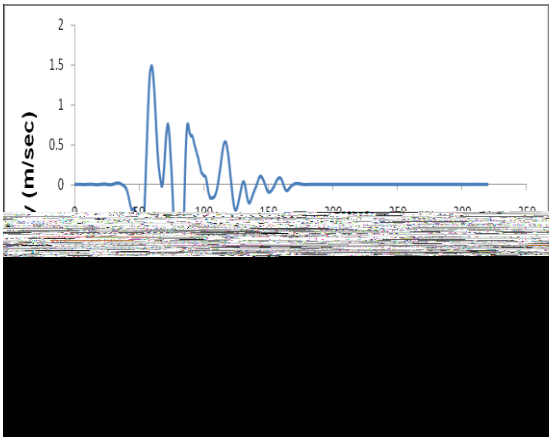

Fig.5 shows the plot of peak ground velocity vs time

Fig.6 shows the plot of peak ground displacement vs time

THREE DIMENSIONAL MODEL

A 3-dimensional model of the dome was modeled in computer program SAP2000 and Dynamic (time history) analysis was performed on the structure to evaluate the structure's response. The model was analyzed for earthquake ground motion data which is obtained from the stochastic model simulation or strong motion simulation. The dimensions of the model are the storey height is 30m, the thickness of the concrete wall is 300mm and the radius of the dome is 20m.Figure 7 shows the SAP2000 model of the domed reactor.

Fig.7 shows the SAP2000 model of the domed reactor

The model was analyzed for one of the earthquake ground motion data which has peak ground acceleration of 0.753m/sec^2 and the displacement time history and response spectrum plots are obtained for the three floors at the respected joints of the domed reactor. The following Figures 8 and 9 shows the displacement time history and response of the joint at the third floor.

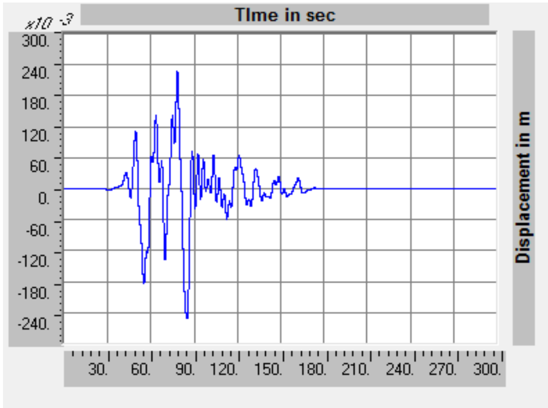

Fig. 8 shows the displacement time history of the joint at the third floor

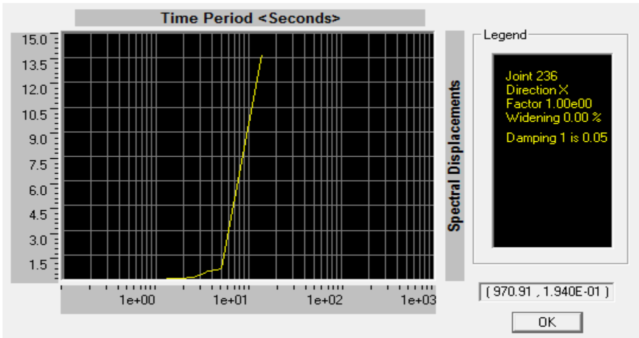

Fig. 9 shows the response of the joint at the third floor

CONCLUSIONS

In this report, the number of faults around the reactor and its location has been discussed. The maximum magnitude of each fault and source parameters for some faults have been determined. The procedure for generating Synthetic accelerogram using the Stochastic Model Simulation (SMSIM).The highest peak ground acceleration obtained by generating the synthetic accelerograms is 0.753m/ sec^2.The synthetic accelerograms generated have the peak ground acceleration of 0.733m/ sec^2, 0.5078 m/ sec^2, 0.55 m/ sec^2, 0.657 m/ sec^2, 0.563 m/ sec^2, 0.51 m/ sec^2, 0.723 m/ sec^2. From the displacement time history of the joints at the three floors it can be seen that there is quite a reduction in the lateral displacements of the structure subjected to earthquake excitation .The structures response has been evaluated and there is a quite reduction from third floor to first floor and hence dynamic analysis of pressurised heavy water reactors have been performed using the acclerogram data obtained.

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