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ANALYSIS OF SEISMIC HAZARD AROUND ROOPPUR NUCLEAR POWER PLANT OF BANGLADESH

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ABSTRACT

The rising expectations for the introduction of nuclear power to solve dire energy shortages and to meet the future increased demand are the priorities for Bangladesh. Nuclear power is a future source of energy; therefore, Bangladesh needs to establish the necessary infrastructure to build a twin unit plant at the Rooppur site, aiming to achieve generation of 2400 MW (e) by the year 2024-2025 respectively. For the realization of a safe and secured project site for the construction of a nuclear power plant, necessary site-specific investigations for the description of geography and demography, geodynamic and seismic conditions, hydrological and morphological characteristics, geological and hydro-geological conditions, meteorological and aerologic situations, man-caused conditions are essential. Procedures are presented for investigating the seismic hazard within the Rooppur Nuclear Power Plant (NPP) construction area. This study reveals the relation between seismic acceleration and potential damage. Such design basis parameters are determined based on the correlation between seismic acceleration versus potential damages due to earthquakes. The geotechnical parameters for the nuclear power project site in Bangladesh have been estimated. The estimated data of the peak ground acceleration and other geophysical parameters described the suitability for the Rooppur NPP. The design basis earthquake safety-related parameters are determined which helps us in determining a suitable nuclear power technology appropriate for Bangladesh.

Keywords: *Geography, Seismic conditions, Hydro-geological, Geotechnical, Peak ground acceleration, Rooppur NPP.*

1. INTRODUCTION

Rooppur NPP is situated on the eastern shore of River Padma in the Pabna District at the distance of approximately 217 km north-west from the capital city Dhaka of the Bangladesh [1,2]. The area of the Rooppur NPP site is nearly 1060 acres.

Rooppur NPP consists of two power units equipped with VVER-type reactors with power capacity of 1,200MW(e) each manufactured under Russian AES-2006 design. The AES-2006 design is based on the principle of safety assurance for the environment personnel and population. Power units are included with active and passive safety systems. The first power unit of the Rooppur NPP is planned to be put into operation in 2024 and the second is scheduled for 2025. Operation life of each of the power units is equal to 60 years existing earthquake magnitude more than 8M with peak ground acceleration 0.33g. This is explained by the availability of positive experience of operation of such power units in the NPPs of India, Turkish and Iran where influence the high magnitude earthquakes. Seismic and Nuclear safety are very important for Bangladesh, as its dislocation of ground and vibrations due to earthquakes. Fukushima-1 NPP of Japan disaster on March 11, 2011 has prompted inquisition to analyze earthquake parameters and the consequences of previous seismic in the Bangladesh.

2. AN OVERVIEW ON GEOTECHNICAL FEATURES OF BANGLADESH

Bangladesh is among the most densely populated country in the world. Much of the country lies in active seismic zones making the occurrence of deadly earthquakes a frightening possibility. Accurate historical information on earthquakes is very important in evaluating the seismicity of Bangladesh in close coincidences with the geotectonic elements. The Seismicity map of Indian subcontinent can provide us with the distribution of past earthquakes. It shows many earthquakes occurred near the proposed project area. The border with the Indian state of Meghalaya is expected to be an active fault zone. The country has suffered severe earthquakes in the past. The seismo-tectonics of proposed site area is influenced by the Kosi Graben (Purnea-Kasganj Graben), the Hoogli Graben and Teesta-Jamina Graben. Earthquakes are fairly common in most parts of this region but their frequency is relatively low. Apart from large earthquakes originating in the Sikkim Himalayas in the northern part of India, tremors have also occurred in and around the site region, along the Indo-Bangladesh border and off the Ganges Delta. There are scores of mild tremors since records have been kept, some right under the Ganges Valley. The area has been severely shaken by large earthquakes, most notably the 1897 Assam earthquake and 1934 Indo-Nepal earthquake [3,4].

Information on earthquakes in and around Bangladesh is available for the last 250 years. The historical earthquake in and around Bangladesh is shown in Table1.

Table 1. Historical earthquake in and around Bangladesh

Year	Latitude	Long-itude	Magnitude (M)	Year	Latitude	Longitude	Magni tude (M)
1762	22	92	7.5	1944	24.7	92.2	6
1764	24	88	6	1950	24.4	91.7	6.3
1845	24.8	91.8	6.5	1951	25.8	90.4	6.8
1846	23.9	89.9	6	1955	22	92.5	6.5
1885	24	90	7	1956	24.8	90.9	6
1897	26	91	8.7	1958	24.9	90.9	5
1911	23	88	5	1960	25.5	89.5	5.2
1918	24.5	91	7.6	1963	24.9	90.5	6.2
1920	22.2	93.2	6	1963	24.8	90.9	6.2
1923	22.6	93.4	6	1967	24	91.5	5.1
1923	25.5	91	7.1	1968	24.1	91.6	5.2
1924	25	93	6	1969	22.9	92.3	5.4
1926	25	93	6	1970	25.7	88.5	5.2
1930	25.8	90.2	7.1	1971	23.8	91.8	5.4
1943	26	93	7.2				

Above the presented data the Roppur NPP is located in the relatively low seismic region of Bangladesh. Most of the seismically active faults in this area are rare. But the possibility of earthquake can't be ignored.

3. METHODOLOGY OF EVALUATION OF PEAK GROUND ACCELERATION (PGA)

One of the important geophysical parameters is the Peak Ground Acceleration (PGA). The PGA due to an earthquake could be measured by installing accelerograph at various locations on the ground. There is thumb rule relation between magnitude, intensity and ground acceleration, which is known as the Medvedev-Sponheuer-Karnik scale MSK or MSK-64. It is a macro-seismic intensity scale used to estimate ground acceleration based on observed effects in the area where an earthquake occurs. Intensity of an earthquake depends on the earthquake magnitude (M), depth of the earthquake focus, distance (of the Rooppur NPP) from the epicenter (d) shown in Fig-1.

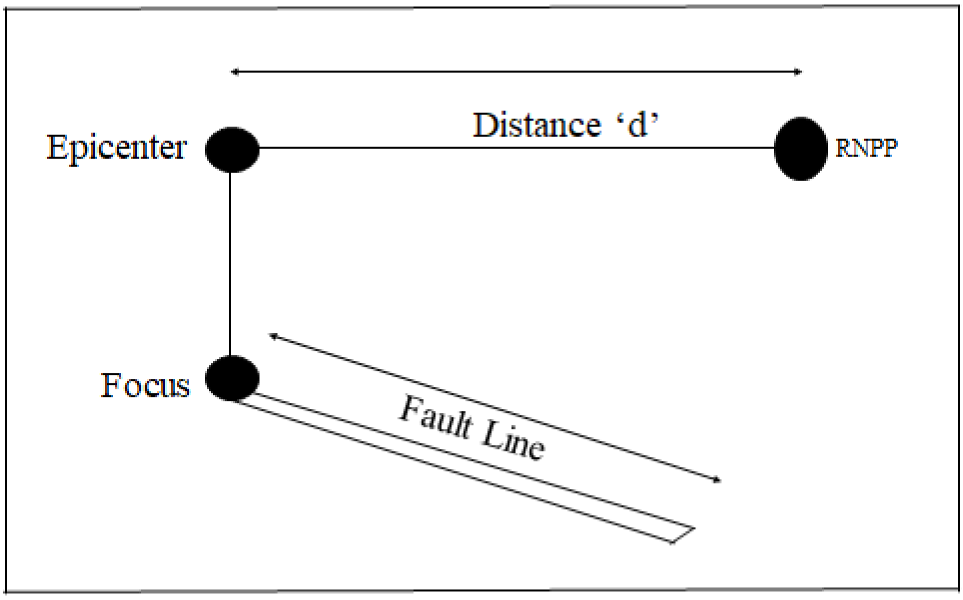

Fig.1: PGA Calculation schematic.

Several numerical approaches for determination of the PGA value have been established. The empirical Duggal’s Equation of motion is one of the best numerical tools for determination of PGA values [5,6]. In our present study, the following Duggal’s Equation has been used to determine the Earthquake Magnitudes against the PGA values. The Duggan’s Equation of motion is as follows:

$$Y=227.3*10^{0.308M}(d+30)^{1.201} \quad \text{...... (1)}$$

Here, Y= Peak Ground Acceleration PGA (in cm/sec^2),

M=Earthquake Magnitude,

d= Distance from epicenter to Rooppur NPP.

on the other hand, Earthquake Magnitude and Earthquake Moment Magnitude calculate two different characteristics of Earthquake. when the energy (E) created by the earthquake and this can be roughly calculated by the converting earthquake magnitude (M) with the equation-

$Log_{10}E_1=11.4+1.5M$ …….. 2

And,

$\frac{E_1}{E_2}=\frac{{r_2}^2}{{r_1}^2}$……... 3

From the equation (2), E_1 is the energy for a specific Earthquake, which is created in the fault line. Then this energy is expanded by the formula- $E=\frac{1}{r^2}$.(Energy is inversely proportional to the square of the distance). From the equation (3), r_1 is the depth to top of Fault line (Fig-1) and r_2 is distance from epicenter to Roppur NPP site. In here, if Earthquake create in a specific fault line, in this moment Earthquake magnitude and the depth of the Fault line are known for this specific fault line. After that, using distance r_2 from this specific Fault line to the Rooppur NPP perceived Earthquake energy (E_2) may be calculated by the help of above equation (3). This perceived Earthquake energy (E_2) is converted to Earthquake Magnitude by using equation (2).

4. RESULT AND DISCUSSION

4.1 Calculation of Geophysical parameters of Rooppur Nuclear Power Project

The site selected for the first nuclear power plant of Bangladesh lies on the eastern bank of the river Ganges (Padma), in the west–central zone of the country. It is situated in the village Rooppur, south of the famous Hardinge Bridge (railway bridge), in the district of Pabna. The frequency of earthquakes in the near-field region of the site is relatively low. Although most of the faults are geologically old and inactive in this part of Bangladesh, and seismically active faults of recent age are rare, the possibility of future Earthquakes cannot be ruled out. It may be of interest to note that the Hardinge Bridge has so far remained totally unaffected by the seismic activities in this region since it's commissioning in 1913.

It is understood that the historical earthquake records suggest that Bangladesh has experienced at least four to five major earthquakes. We have derived the intensity of the magnitude of the historical earthquake of Bangladesh. It is seen from Table 2 that historically Bangladesh has been affected by five Earthquakes of large magnitude during the 61-year period from 1869 to 1930.

Table 2. List of Major Earthquake Affecting Bangladesh

Date	Name of earthquake	Magnitude M (Richter scale)	Approximate Epicenter Distance from Rooppur NPP site(km)
1664	Bangla Earthquake	7.8	92
1869	Cachar Earthquake	7.5	290
1885	Bengal Earthquake	7.0	90
1897	Grate Indian Earthquake	8.7	242
1918	Srimangal Earthquake	7.6	270
1930	Dhubri Earthquake	7.1	237

It is seen from the estimated data of the Table-2 that the magnitude was in the range between 7(M) and 8.7(M). In Table-2 it is also observed that, in 1897 the magnitude of the earthquake was maximum and in Richter scale it was 8.7(M).

Based on available geological and geotechnical characteristics, the subsoil investigations, geotechnical and site-specific seismic hazard assessment are the vital areas of investigation for the selection of a Rooppur NPP site in Bangladesh. necessary steps have been taken to examine the suitability of Rooppur NPP site for NPP construction.

Using the major historical data from Table 2, we have estimated the PGA values of five major earthquakes by using the Equation Peak Ground Acceleration $Y(PGA)=227.3*10^{0.308M}(d+30)^{-1.201}$. The calculated data of the PGA values are shown in Table 3 below.

Table 3. Magnitude and PGA

PGA(g)	Magnitude M (Richter scale)	Approximate Epicenter distance from Rooppur NPP site (km)
0.18	7.8	92
0.05	7.5	290
0.11	7	90
0.13	8.7	242
0.054	7.6	270

The peak ground acceleration (PGA) is estimated 0.18g for the return period of 2475 year which is even much smaller than the designed basis PGA values of the (Rooppur NPP) nuclear reactor. It is well known that, Earthquake is not created everywhere in the Earth, but it is created in the fault line [7,8,9]. We have also reviewed the fault line location in an around Rooppur NPP Project. Considering geology and the area bounded by a circle of 300km radius, six tectonic blocks can be identified which have been active in producing earthquakes. These are shown in Fig.2.

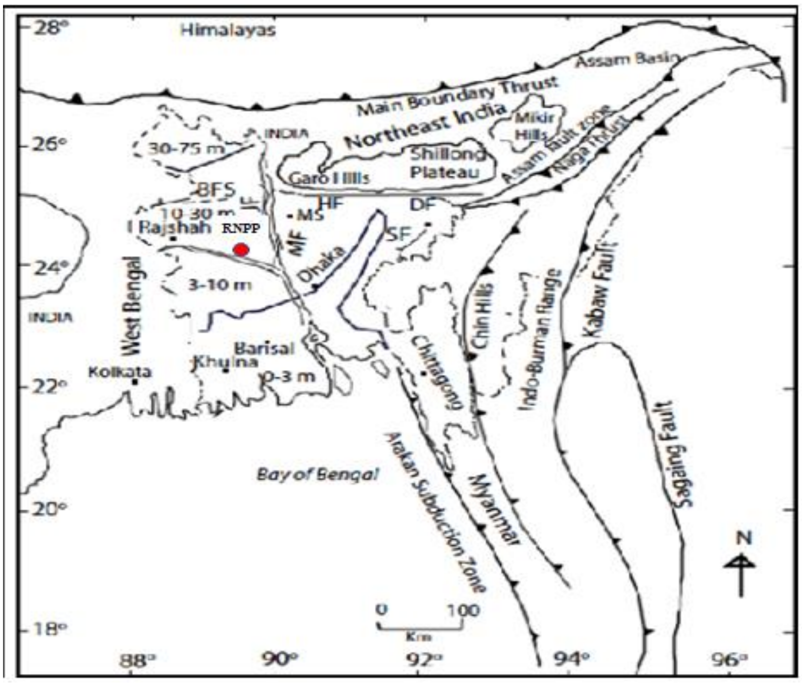

Fig.2: BF- Bogra Fault System, DF- Dauki Fault, JF- Jamuna Fault, MF- Madhupur Fault, SF- Sylhet Fault and Shillong plateau fault zone.

The different parameters of the faults have been determined and are shown in Table 4. below.

Table 4. Parameters of different fault in Bangladesh

Fault	Magnitude M (Richter scale)	Depth to top of Fault(km)	Fault Type
Madhupur fault (Tangile)	7.5	10	Reverse/May occur earthquake
Dauki Fault (Sylhet)	8.0	3	Reverse
Plate boundary -1	8.5	3	Reverse
Plate boundary-2	8.0	3	Reverse

It has been realized that, there is no indication of surface faulting around Rooppur NPP site and seismically active faults within 20 km radius are rare, which is shown in the Fig.2. There is no evidence of happening earthquake of maximum intensity in an around Rooppur NPP site, we have estimated the PGA value in Rooppur NPP site due to the maximum possible earthquakes magnitude say 9(M) (Richter scale) that may originate in Madhupur fault (Tangail) [10,11]. Madhupur Fault is a possible source for an earthquake that occurred in 1885. The aerial distance between Madhupur and Rooppur NPP site of about 161 km. For this estimated PGA value in Rooppur NPP site would be 244.9505cm/sec^2 (0.25g) by using equation (1). From this calculated, it can be concluded on the basis of estimated PGA value that the maximum earthquake magnitude in Rooppur NPP would be 7.4M.

By using equation (2) and (3) the maximum possible earthquake magnitude which may generate in Madhupur Fault (For an approximately aerial distant between Madhupur Fault and Rooppur is 161 km) and feeling earthquake in Rooppur site shown in Table 5.

Table 5. The estimated data of maximum possible earthquake in Madhupur Fault and feeling in Rooppur site.

Earthquake in Madhupur Fault (M)	Feeling Earthquake in Rooppur Site (M)
9 (Assumption)	7.4
8.5(Assumption)	6.9
8(Assumption)	6.4
7.5 Historical data	5.9
7 May be occur	5.4

It can be seen from the Table-5 that, the strongest assumption and closely Magnitude Earthquake sources at the Madhupur Fault, the intensity of seismic impact on the Rooppur NPP site does not exceed the magnitude level 8M.

The Dawki fault is a major fault along the southern border of the Shillong Plateau that can be a source of destructive earthquake hazard for neighboring regions, including Rooppur NPP and northeastern part of Bangladesh. The inferred fault passing through the southern edge of the Shillong Plateau is an east-west-trending north-tilting reverse fault [12,13,14]. In the same way it may calculate the Earthquake to be generated in the Dauki fault and feeling Earthquake in Rooppur site. For an aerial distant between Dauki Fault and Rooppur NPP is 285 km and the estimated data of maximum possible earthquake level at Roppur NPP site is shown in Table 6.

Table 6. The estimated data of maximum possible Earthquake in Dauki fault and feeling in Rooppur site.

If create Earthquake in Dauki Fault (M)	Feeling Earthquake in Rooppur NPP Site (M)
9 (Assumption)	6.4
8.5(Assumption)	5.9
8 Historical data	5.4
7.5May be occur	4.9
7.0 May be occur	4.4

It can be seen from the Table 6. that, the strongest assumption and closely Magnitude Earthquake sources at the Dauki Fault, the intensity of seismic impact on the Rooppur NPP site does not exceed the magnitude level 8M. Similarly, it can be said that, if Plate Boundary Fault-1 and Plate Boundary Fault-2 will generate the maximum Earthquake, then the feeling Earthquake in the Rooppur NPP site will not exceed the level 8.0M.

From the seismic hazard analyses and sub-soil investigation it is clear that, if maximum earthquake is created in the fault line Madhupur and Dauki 9M (Assumption), then the feeling earthquake in Rooppur NPP site will be 7.4M and 6.4M respectively. On the other hand, PGA value will be 0.25g and 0.14g accordingly. But heavy structures like NPP with larger design basis PGA values about 0.333g under construction at Rooppur site could withstand an Earthquake of the range 8(M). For this, First Nuclear Power Plant of Bangladesh (Rooppur NPP) will be strong and longevity.

5. CONCULASION

In this article it is understood that, the Rooppur NPP site is in seismically stable area with minimum threat from the seismic, tsunami and other natural hazards. The construction of Rooppur NPP is an important means of providing uninterruptedly energy supply to Bangladesh for a long time in the shortest possible time. The Russian VVER 3+ design contains all the elements obligate to ensure efficient earthquake protection of Rooppur NPP equipment’s and provided protection against seismic hazards taking into account site specific seismic conditions. Accounting for predicted seismic impacts exceeding historically recorded levels should be ensured by the creation of an additional effective seismic analysis system and timely transfer to the Rooppur NPP.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest regarding the publication of this article.

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