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# Peak Ground Acceleration Analysis using Past Earthquake Data

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# Peak Ground Acceleration Analysis using Past Earthquake Data

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**Abstract.** Peak Ground Acceleration (PGA) is one of the important parameters in the design of seismic resistant structures. In order to predict the value of PGA for a particular place, the past seismic history of that place in terms of data sets is required. The seismic data analysis of regions or nations becomes mandatory due to the frequent occurrence of earthquakes worldwide. This paper presents a study to predict peak ground acceleration of Maharashtra, India by using Excel and MATLAB tools. The available parameters used for the prediction are PGA, epicentral distance, depth and moment magnitude from the year 1912 to 2009. Both the tools have good fit in the prediction of PGA of Maharashtra ($R^2$ >0.9); however Excel may be preferred because of its simplicity and flexibility in handling the data sets.

## 1. Introduction

Earthquakes are the natural disaster that kill hundreds and thousands of people, destroy property and leave a long lasting damage on the environment. Generally, immediately after an earthquake event a partial report on the earthquakes will be available. The data can be collected from newspapers, media etc. In order to understand the severity of the earthquake, parameters like depth, magnitude, intensity, epicenter and the effects of earthquake from past seismic history of the location are to be known.(Jaiswal and Sinha, 2008; Sankar and Kiran, 2011; Anbazhagan and Abhisek, 2013). The prediction of ground motion parameter like peak ground acceleration (PGA) in terms of epicentral distance, depth, magnitude, intensity, peak ground velocity, peak horizontal acceleration is a major research area for carrying out seismic data analysis (Iyengar, 1999; David, 1999, John, 2019). The past data should be analyzed for its reliability using data analysis. The missing data can be obtained from this analysis. In this study magnitude, depth and epicentral distance and PGA of earthquakes have been used as input parameters for the prediction analysis in Excel and MATLAB. R square results from regression analysis show that the parameters are correlated well. This paper includes the data set for Maharashtra State of India and also the relationship between PGA, epicentral distance, depth and magnitude for the available data.

## 2. Study area

Maharashtra is the state in the western peninsular region of India occupying a substantial portion of the Deccan plateau (figure 1). It is the second most populous state and third largest state by area, spread over 307,713 $km^2$ (118,809 sq mi). Latitude and longitude coordinates are 19.076090 and

72.877426. According to the seismic zonation of India given in IS 1893-2016, Part 1(Criteria for earthquake resistant design of structures), Maharashtra falls in zone III which is having the possibility of covering intensity up to VII or more (Jyoti Sarup, 2006). The state has experienced earthquakes of up to 6.2$M_w$ with the intensity of VIII (Severe) in a depth of 12 km i.e. Latur earthquake in 1993. The quake affected the districts of Latur and Osmanabad.

**Figure 1.** Map of India with Study Area – Maharashtra.

### 3. Methodology

The methodology for the current study is given in figure 2. From the literature survey, the objectives for the prediction of Peak Ground Acceleration (PGA) for Maharastra state are formed. The past occurrence of earthquakes in Maharastra from the year 1912 to 2009 is collected and analysed using MATLAB Microsoft Excel. The predicted PGA values are compared with the actual PGA values.

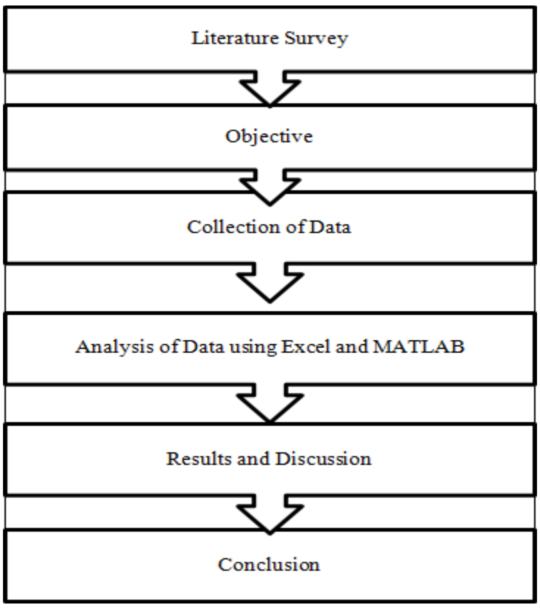


**Figure 2.** Methodology.

## 4. Data used
The seismic data pertaining to Maharastra state such as year of its occurrence, intensity, epicentral distance, depth, magnitude and recorded PGA are collected and given in table 1.

**Table 1**. Significant seismic data of Maharashtra from 1912 to 2009.

| Year | Intensity | Epicentral Distance (m) | Depth (m) | Magnitude ($M_W$) | PGA |
|---|---|---|---|---|---|
| 1912 | I | 14.4 | 10 | 4.6 | 3.3 |
| 1912 | II | 15.2 | 10 | 4 | 2.6 |
| 1912 | V | 15.6 | 10 | 6.7 | 5.3 |
| 1912 | V | 16.5 | 24.99 | 5.3 | 3.39 |
| 1912 | V | 17.6 | 10 | 6.5 | 5.1 |
| 1918 | I | 18.4 | 10 | 3.9 | 2.6 |
| 1924 | II | 19.5 | 30 | 4.7 | 3.3 |
| 1924 | II | 19.6 | 10 | 3.6 | 2.2 |
| 1930 | II | 19.9 | 10 | 4.7 | 3.3 |
| 1930 | II | 19.9 | 10 | 4.4 | 3.0 |
| 1930 | II | 20.0 | 10 | 4.2 | 2.8 |
| 1930 | II | 20.0 | 35 | 4.7 | 3.3 |
| 1930 | III | 20.1 | 10 | 4.4 | 3.0 |
| 1930 | III | 169.4 | 10 | 4.7 | 3.3 |
| 1930 | IV | 170.0 | 10 | 3.7 | 2.3 |
| 1930 | II | 170.2 | 10 | 3.6 | 2.2 |
| 1933 | II | 170.3 | 10 | 5.4 | 4.0 |
| 1934 | II | 171.0 | 42.36 | 4.5 | 3.1 |
| 1934 | II | 171.1 | 10 | 4.5 | 3.1 |
| 1934 | III | 171.5 | 10 | 4.6 | 3.2 |
| 1934 | III | 172.6 | 32.95 | 4.9 | 3.5 |
| 1934 | III | 173.4 | 17.07 | 4.8 | 3.4 |
| 1934 | III | 175.3 | 17.14 | 4.3 | 2.9 |
| 1934 | IV | 175.4 | 32.13 | 6.1 | 4.7 |

| | | | | | |
|---|---|---|---|---|---|
| 1934 | IV | 176 | 29.78 | 5.5 | 4.1 |
| 1934 | IV | 177.1 | 32.34 | 5.1 | 3.7 |
| 1934 | IV | 177.5 | 27.78 | 6.1 | 4.7 |
| 1934 | IV | 178.0 | 10 | 5.4 | 4.0 |
| 1934 | V | 178.2 | 33.56 | 6.1 | 4.7 |
| 1938 | IV | 178.3 | 30.06 | 5.5 | 4.1 |
| 1938 | V | 178.3 | 20.94 | 6.4 | 5.0 |
| 1967 | IV | 180.0 | 27.71 | 6.4 | 5.0 |
| 1967 | IV | 180.6 | 30.04 | 5.5 | 4.1 |
| 1967 | IV | 181.2 | 10 | 6.2 | 4.8 |
| 1967 | IV | 181.8 | 10 | 5.1 | 3.7 |
| 1967 | V | 182.4 | 22.65 | 6.5 | 5.1 |
| 1967 | V | 183.1 | 27.86 | 7.2 | 5.8 |
| 1969 | II | 183.7 | 30.67 | 4.9 | 3.5 |
| 1969 | III | 38.0 | 26.52 | 4.7 | 3.3 |
| 1993 | IV | 39.4 | 30.78 | 4.9 | 3.5 |
| 2000 | III | 39.5 | 30.39 | 4.3 | 2.9 |
| 2001 | III | 39.7 | 29.31 | 5 | 3.6 |
| 2001 | V | 40.1 | 29.47 | 4.8 | 3.4 |
| 2001 | II | 40.4 | 29.72 | 4.2 | 2.8 |
| 2003 | III | 40.5 | 35 | 4.6 | 3.2 |
| 2003 | III | 42.9 | 30.62 | 4.1 | 2.7 |
| 2004 | III | 42.0 | 29.61 | 4.3 | 2.9 |
| 2004 | IV | 42.0 | 43.76 | 4.9 | 3.5 |
| 2005 | III | 42.2 | 49.34 | 4.6 | 3.2 |
| 2005 | IV | 42.6 | 30.65 | 4.6 | 3.2 |
| 2007 | IV | 42.8 | 39.08 | 5.2 | 3.8 |
| 2009 | IV | 43.4 | 27.11 | 4.2 | 2.8 |
| 2009 | III | 43.7 | 28.11 | 4 | 2.6 |

## 5. Results and discussion

The regression analysis of the available data is carried out using Excel and MATLAB tools and the results are provided in tables 2, 3 and 4, respectively.

**Table 2.** Results from Excel.

| Excel output | |
|---|---|
| Intercept | -1.31557 |
| X (Epicentral distance) | -3.7E-05 |
| Y (Depth) | -0.00064 |
| Z (Magnitude) | 0.987311 |

**Table 3.** Results from regression.

| Regression statistics | |
|---|---|
| Multiple R | 0.999568 |
| R Square | 0.999135 |
| Adjusted R Square | 0.999082 |

The equation as given in Equation (1) from the regression analysis is used for the prediction of PGA values.

$$PGA = -1.31557 - 0.000037(X) - 0.00064(Y) + 0.987311(Z) \quad (1)$$

The procedure followed in the MATLAB programme is explained below.
Algorithm used:
$X = [\text{ones}\ (\text{size}(X_1))\ X_1\ X_2\ X_3\ X_1.*X_2.*X_3]$
$X_1$ – Epicentral Distance
$X_2$ – Depth
$X_3$ – Magnitude
Results:
-1.3155700
-3.699927e-05
-0.0006399
0.98731100

**Table 4.** Results from MATLAB.

| MATLAB output | |
|---|---|
| Root Mean Square Error | 0.213 |
| R Squared | 0.94 |
| Mean Absolute Error | 0.1507 |
| Mean Square Error | 0.04537 |

Figures 3 to 5 show the correlation of the predicted PGA with the epicentral distance, depth and magnitude of earthquakes. It is observed that the magnitude is highly correlated with the PGA than other two parameters.

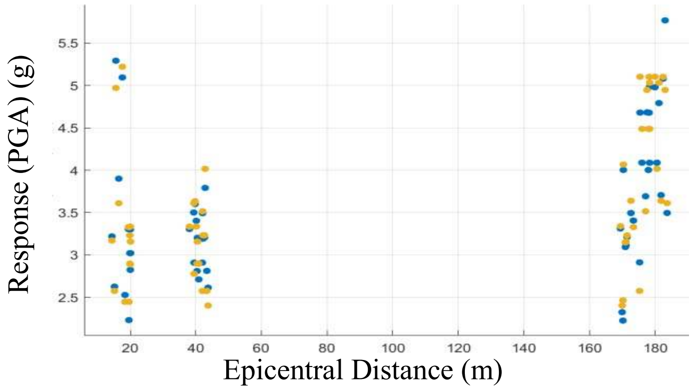


**Figure 3.** Prediction PGA versus Epicentral Distance.

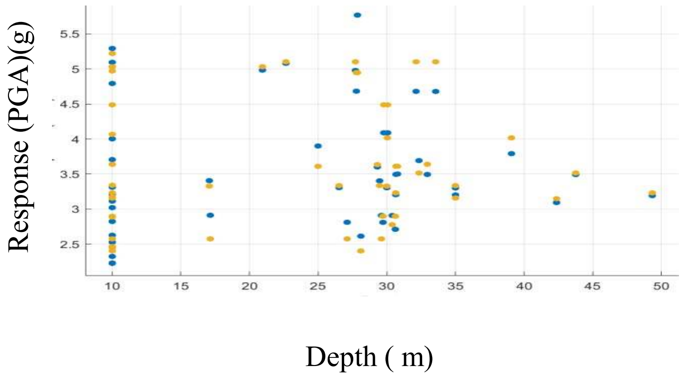


**Figure 4.** Prediction PGA versus Depth.

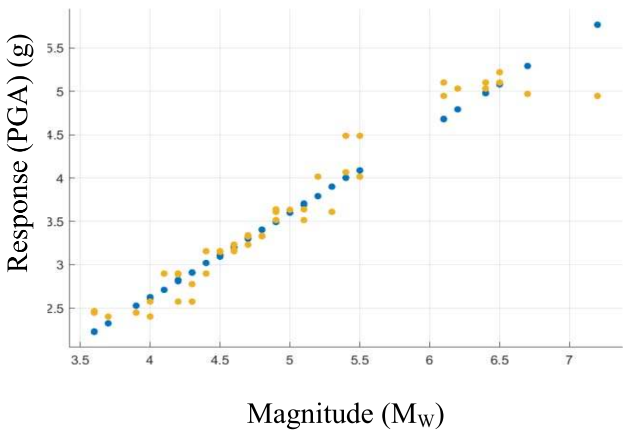


**Figure 5.** Prediction PGA versus Magnitude.

Figure 6 shows the perfect correlation of the predicted with the available data.

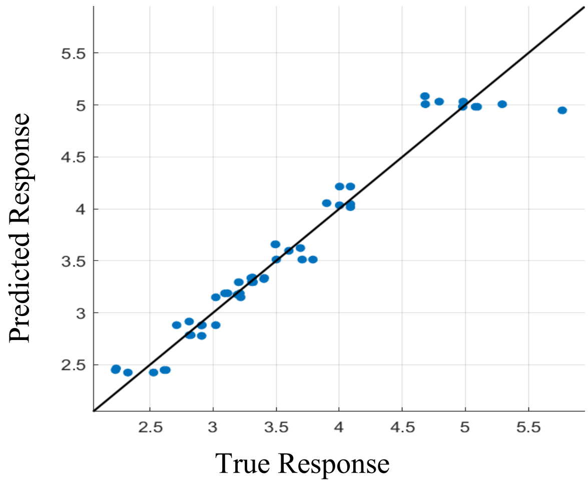


**Figure 6.** Correlation between predicted response and true response.

## 6. Conclusion

From this study, it is observed that the predicted Peak Ground Acceleration is reliable as it has perfect correlation with the available data. By comparing the R square value from Excel (0.999) and MATLAB (0.94), the difference is only around 6 %. From the present study it is concluded that the prediction of PGA of any site can be found using simple procedure in excel and MATLAB.

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