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 (R² >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 km² (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 6.2Mw 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.

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 Maharashtra state are formed. The past occurrence of earthquakes in Maharashtra 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 1. Map of India with Study Area – Maharashtra.

Figure 2. Methodology.
4. Data used
The seismic data pertaining to Maharashtra 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 (MW) | 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  |
| Year | IV | V     | W    | X    | Y    |
|------|----|-------|------|------|------|
| 1934 | 176| 29.78 | 5.5  | 4.1  |
| 1934 | 177.1| 32.34 | 5.1  | 3.7  |
| 1934 | 177.5| 27.78 | 6.1  | 4.7  |
| 1934 | 178.0| 10    | 5.4  | 4.0  |
| 1934 | 178.2| 33.56 | 6.1  | 4.7  |
| 1938 | 178.3| 30.06 | 5.5  | 4.1  |
| 1938 | 178.3| 20.94 | 6.4  | 5.0  |
| 1967 | 180.0| 27.71 | 6.4  | 5.0  |
| 1967 | 180.6| 30.04 | 5.5  | 4.1  |
| 1967 | 181.2| 10    | 6.2  | 4.8  |
| 1967 | 181.8| 10    | 5.1  | 3.7  |
| 1967 | 182.4| 22.65 | 6.5  | 5.1  |
| 1967 | 183.1| 27.86 | 7.2  | 5.8  |
| 1969 | 183.7| 30.67 | 4.9  | 3.5  |
| 1969 | 38.0 | 26.52 | 4.7  | 3.3  |
| 1993 | 39.4 | 30.78 | 4.9  | 3.5  |
| 2000 | 39.5 | 30.39 | 4.3  | 2.9  |
| 2001 | 39.7 | 29.31 | 5    | 3.6  |
| 2001 | 40.1 | 29.47 | 4.8  | 3.4  |
| 2001 | 40.4 | 29.72 | 4.2  | 2.8  |
| 2003 | 40.5 | 35    | 4.6  | 3.2  |
| 2003 | 42.9 | 30.62 | 4.1  | 2.7  |
| 2004 | 42.0 | 29.61 | 4.3  | 2.9  |
| 2004 | 42.0 | 43.76 | 4.9  | 3.5  |
| 2005 | 42.2 | 49.34 | 4.6  | 3.2  |
| 2005 | 42.6 | 30.65 | 4.6  | 3.2  |
| 2007 | 42.8 | 39.08 | 5.2  | 3.8  |
| 2009 | 43.4 | 27.11 | 4.2  | 2.8  |
| 2009 | 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.

\[
\text{PGA} = -1.31557 - 0.000037(X) - 0.00064(Y) + 0.987311(Z)
\]  

(1)

The procedure followed in the MATLAB programme is explained below.

Algorithm used:

\[
\begin{align*}
X &= \text{ones (size}(X_1)) \times X_1 \times X_3 \times X_1 \times X_2 \times X_3 \times X_1 \times X_2 \times X_3 \\
X_1 &\text{ – Epicentral Distance} \\
X_2 &\text{ – Depth} \\
X_3 &\text{ – Magnitude} \\
\end{align*}
\]

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.](image)

### 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.

### References

[1] Amit Shiuly, Narayan Roy and Ramendu Bikas Sahu 2020 Prediction of peak ground acceleration for Himalayan region using artificial neural network and genetic algorithm, *Arab J Geosci* 13 215

[2] Anbazhagan P, Abhishek Kumar and Sitharam T G 2013 Ground motion prediction equation considering combined dataset of recorded and simulated ground motions *Soil Dynamics and Earthquake Engineering* 53 92-108

[3] Bindi D, Massa M, Luzi L, Ameri G, Pacor F, Puglia R and Augliera P 2014 Pan-European ground-motion prediction equations for the average horizontal component of PGA, PGV, and 5%-damped PSA at spectral periods up to 3.0 s using the resource dataset, *Bulletin of Earthquake Engineering* 12 391-430

[4] David J. Wald, Vincent Quitoriano, Thomas H. Heaton, M.EERI and Hiroo Kanamori 1999 Relationships between Peak Ground Acceleration, Peak Ground Velocity, and Modified Mercalli Intensity in California *Earthquake Spectra*, 15(3)

[5] Gangrade B K and Arora S K 2000 Seismicity of the Indian Peninsular Shield from Regional Earthquake Data *Pure and applied geophy* 157 1683-1705

[6] Iyengar R N, Devendra Sharma and Siddiqui J M 1999 Earthquake history of India in medieval times *Indian Journal of History of Science* 34(3)

[7] John Douglas 2019 Ground motion prediction equations *Department of Civil and Environmental Engineering*, Report
[8] Jyoti Sarup, M. Muthukumaran, Nitin Mathur and V. Peshwa 2006 Study of tectonics in relation to the seismic activity of the Dalvat area, Nasik District, Maharashtra, India using remote sensing and GIS techniques International Journal of Remote Sensing 27 (12) 2371-2387

[9] Keshri, C. K., Mohanty, W. K 2018 Ground-Motion Prediction Equations for the Geometric mean of Horizontal Component of Peak Ground Acceleration, and 5%-Damped Pseudo-Spectral Acceleration at Spectral Periods between 0.01s and 8.0s for Indo-Gangetic Plains, India American Geophysical Union

[10] Marzieh Ahmadi, AliNasroolahnejad, Alireza Faraji 2017 Prediction of peak ground acceleration for earthquakes by using intelligent methods 5th Iranian Joint Congress on Fuzzy and Intelligent Systems

[11] Murphy J R and O’Brien L J 1977 The correlation of peak ground acceleration amplitude with seismic intensity and other physical parameters Bulletin of the Seismological Society of America 877-915

[12] Sankar Kumar Nath and Kiran Kumar Singh Thingbaijam 2011 Peak ground motion predictions in India: an appraisal for rock sites Journal of Seismology 15 295-315

[13] Surendar Kumar 1998 Intraplate seismicity and geotectonics near the focal area of the Latur earthquake (Maharashtra), India Journal of Geodynamics 25 (1-2) 109-128

[14] Zafarani H, Lucia Luzi, Giovanni Lanzano and Soghret M R 2018 Empirical equations for the prediction of PGA and pseudo spectral accelerations using Iranian strong- motion data Journal of Seismology 22 263-285