Seismic Hazard Assessment for Northern Egypt: Insights from Earthquake Catalog Analysis and Gutenberg-Richter Parameters

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Keywords : earthquakes, seismicity, site selection, northern Egypt

1. Introduction

Northern Egypt lies within a seismically active zone, shaped by the dynamic interactions of the African and Eurasian tectonic plates. The region experiences moderate seismic activity due to the convergence and relative motion of these plates. With growing interest in infrastructure development, including nuclear power plants, in Northern Egypt, it is essential to conduct thorough seismic hazard assessments to ensure the safety of critical nuclear infrastructure. A key component in seismic hazard assessments is the characterization of seismic sources, which underscores the importance of understanding the seismicity of the Northern Egypt region.

The Gutenberg-Richter recurrence law is a widely used model for describing seismicity, relating the number of earthquakes to their magnitude [1]. However, the original studies on the Gutenberg-Richter recurrence law used on magnitude type, which is a significant hurdle to overcome considering how many different earthquake magnitude types are reported across different earthquake catalogs. Magnitude types such as body wave magnitude m_b, surface wave magnitude M_S, surface magnitude measured in the vertical direction, M_{SZ}, local magnitude M_L, and moment magnitude M_W [2-4]. To address this, magnitude homogenization is required to convert all magnitude types to a unified scale, typically Mw, which is considered more reliable for seismic analysis [5].

This study aims to characterize the seismicity of Northern Egypt by compiling earthquake data and estimating the appropriate Gutenberg-Richter parameters. The findings will contribute to more reliable seismic hazard assessments for nuclear infrastructure projects in the region.

2. Methods and Results

2.1 Data Collection

The earthquake data utilized in this research is obtained from the International Seismological Centre (ISC) Bulletin [6-7], which consolidates records of earthquakes worldwide dating back to 1900. The ISC Bulletin integrates information from various institutions, including the United States National Earthquake Information Center (NEIC) and the Global Centroid Moment Tensor (GCMT) project. To further refine the accuracy and consistency of the dataset, data from the ISC-GEM catalog [8], which offers enhanced earthquake parameter estimates, is also incorporated.

A total of 5,234 earthquakes were recorded in Northern Egypt, with their epicenters illustrated in Fig. 1. The figure shows that most of the seismic activity is located in the northeastern region of Egypt, around the Sinai peninsula.

Fig. 1. Epicenters of earthquakes of the Northern Egypt region shown in red.

2.2 Magnitude Homogenization

In this research, various magnitude types were converted into a single, standardized moment magnitude scale M_W. M_W is preferred in earthquake studies because it is based on physically meaningful parameters that offer sa reliable measure of earthquake energy release across a broad range of magnitudes. Unlike Ms or m_b, which tends to saturate at higher magnitudes, Mw remains stable. Moreover, many models and components in connecting seismic hazard analysis use M_W for input.

To achieve this magnitude homogenization in the earthquake catalog, empirical correlations developed for the African region were utilized [5]. These correlations provide a structured approach for magnitude homogenization, drawing on comprehensive global and regional data. Table 1 presents a list of the magnitude homogenization relationships used in this study.

Table 1: Regression relationships for magnitude homogenization [5].

Agency/Magnitude	Conversion		σ
ISC M_S	$M_w^{PROXY} = 0.616M_S^{ISC} + 2.369$	if $M_S^{ISC} \leq 6.0$	0.147
	$M_w^{PROXY} = 0.994M_S^{ISC} + 0.1$	if $M_S^{ISC} > 6.0$	0.174
NEIC M_S	$M_w^{PROXY} = 0.723M_S^{NEIC} + 1.798$	if $M_S^{NEIC} \leq 6.47$	0.159
	$M_w^{PROXY} = 1.005M_S^{NEIC} + 0.026$	if $M_S^{NEIC} > 6.47$	0.187
NEIC M_{SZ}	$M_w^{PROXY} = 0.707M_{SZ}^{NEIC} + 1.933$	if $M_{SZ}^{NEIC} \leq 6.47$	0.179
	$M_w^{PROXY} = 0.950M_{SZ}^{NEIC} + 0.359$	if $M_{SZ}^{NEIC} > 6.47$	0.204
NEIC m_b	$M_w^{PROXY} = 1.159\ M_b^{NEIC} - 0.659$		0.283
ISC m_b	$M_w^{PROXY} = 1.084m_b^{ISC} - 0.142$		0.317

Selecting the most accurate regression relationship based on the smallest standard deviation. When an earthquake catalog entry reported multiple magnitude types without an explicit M_W, the homogenization relationship with the lowest standard deviation is applied. This approach ensures consistent magnitude representation across the dataset.

2.3 Gutenberg-Richter Analysis

The Gutenberg-Richter recurrence law was applied to the dataset. A plot was generated with M_W on the x-axis and the cumulative number of earthquakes (in logarithmic scale) on the y-axis. The data points were fitted using linear regression to determine the Gutenberg-Richter coefficients a and b. The resulting plot is shown in Fig. 2. The regression yielded values of a = 5.144 and b = 0.646.

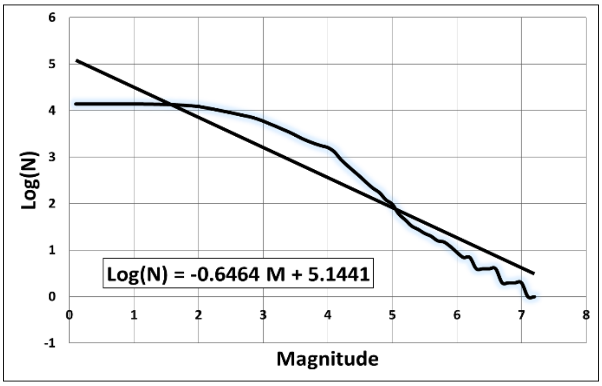

Fig. 2. Gutenberg Richter recurrence relationship.

The b-value of the Gutenberg-Richter relationship describes how quickly the number of earthquakes decreases as magnitude increases. Higher b-values (e.g., 1.0 or greater) indicate a steeper decline, meaning small earthquakes are much more frequent, and large earthquakes are rare. In contrast, a lower b-value, such as 0.646 in the case of Northern Egypt, suggests a less steep decline, indicating a relatively higher proportion of moderate to large earthquakes. The intercept a-value represents the overall level of seismicity in the region, as it marks the intersection of the trendline with the Y-axis; a higher a-value reflects a higher overall seismicity level, while the a-value of 5.144 indicates a moderate level of overall seismicity.

3. Conclusions

This study characterized the seismicity of the Northern Egypt Region by compiling 5,234 earthquakes from the ISC Bulletin and ISC-GEM catalog. Magnitude homogenization was applied to convert various magnitude scales into the moment magnitude Mw, ensuring consistency in the dataset. The Gutenberg-Richter recurrence law was then applied, yielding the parameters a=5.144 and b=0.646. The relatively low b-value suggests a relatively higher proportion of moderate to large earthquakes compared to regions with higher b-values, while the a-value indicates a moderate level of overall seismicity.

These findings provide a reliable basis for seismic hazard assessments in Northern Egypt, particularly for critical infrastructure projects such as nuclear power plants. The study highlights the importance of understanding regional seismicity for ensuring safety and resilience in infrastructure development.

Future work could expand on this by incorporating additional data sources and refining magnitude homogenization techniques.

Acknowledgement

This research was supported by the 2025 Research Fund of the KEPCO International Nuclear Graduate School (KINGS), the Republic of Korea.

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