Combining Historical Earthquake Data with Modern Instrumented Record for Reliable Recurrence Rate Calculation in Seismicity

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1. Introduction

Prior to the 2016 Gyeongju and 2017 Pohang earthquakes, South Korea was not known to be a region of high seismicity [1-2]. These events changed how Korean society viewed earthquakes, especially how safe the numerous nuclear power plants were given the events at the Fukushima nuclear disaster in 2011. The 2011 Fukushima nuclear disaster was the result of a tsunami caused by a massive earthquake off the eastern shore of Japan [3]. Nonetheless, there is not much data for detailed earthquake studies in South Korea, which makes it difficult to conduct reliable safety assessments when considering seismic events. For example, in the past 45 years, there have been only 8 events total with a local magnitude greater than or equal to 5.0. Although a 5.0 local magnitude event is generally not considered very dangerous, certain site and source effects can amplify motions to cause damage.

One of the first steps in such seismic safety studies is the estimation of seismicity parameters. However, give the paucity of earthquake data, additional sources or methods will need to be considered. This study takes into account a record of macroseismic events to expand on the database of earthquake events for South Korea for parameterization of seismicity.

2. Methods and Results

A recurrence law formulated by Gutenberg and Richter describes the total number of earthquakes above a certain magnitude to follow a logarithmic pattern [4]. This pattern is described in Eq. (1):

$$\log (N) = a - bm \qquad (1)$$

where N represents the total number of earthquakes greater than or equal to the magnitude m, with regression constants labeled as a and b. The a-value is related to the seismic activity per year and can be thought of as the total number of earthquakes in the study period, while the b-value is the slope of the recurrence relationship, which is a relative measure between strong and weak earthquakes. Typically, b-values are close to 1.0.

Earthquake data were compiled from the International Seismological Centre and the Korea Meteorological Administration [5-6]. The period of study was from 1900 to 2020, which is the maximum time window for the International Seismological Centre. Offshore events within 200 km were considered in this study. A map displaying the epicenters of all the events is shown in Figure 1. The map categorizes the study area into 6 sections. The delineating borders were generally drawn by eye, considering where most clusters of earthquakes occurred visually. Note that zones 1 and 2 include portions of North Korea, while zone 6 includes parts of Japan.

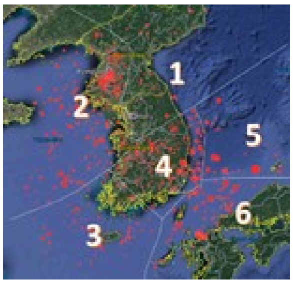

Fig. 1. Seismic source zones for South Korea used in this study.

To complement these events, a compiled list of earthquakes from the Korea Meteorological Agency of events from 2 to 1904 is also considered [7]. Although these earthquakes do not have an instrumented recording for magnitude estimation, the Korea Meteorological Agency utilized several relationships mapping observations to an estimated magnitude, thus making these macroseismic events. By using this additional data, the earthquakes available for study are extended by an additional 2,111 events. These events are more typically known as historical earthquakes in South Korean vernacular. Figure 2 shows the distribution of earthquakes taken from the historical macroseismic study and those recorded on modern instruments.

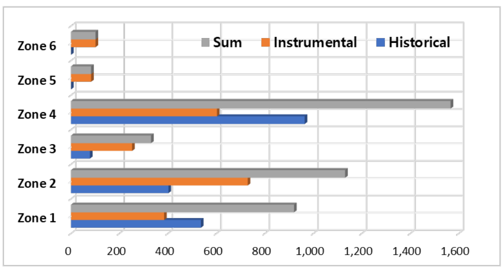

Fig. 2. Number of historical and instrumented earthquakes in each zone.

A plot of the number of earthquakes with magnitude greater than or equal to magnitude m against magnitude m is shown in Figure 3. This figure considers all compiled data for zone 1. The regressed a and b-value parameters are listed as 4.01 and 0.55, respectively.

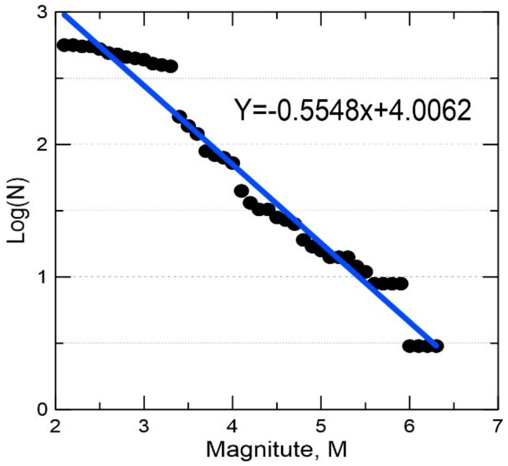

Fig. 3. Sample plot of seismicity when considering events from 2 till 2020.

A plot of the number of earthquakes with magnitude greater than or equal to magnitude m against magnitude m is shown in Figure 4. However, this figure considers all data for zone 1 from 1393 till 2020. The Choseon dynasty is considered to have started around 1393 with a larger and relatively more sophisticated populace than previous Korean dynasties suggesting their observations would be slightly more reliable. The regressed a and b-value parameters are listed as 4.20 and 0.62, respectively. The increase in the a-value is minute relative to the number of events, but the increase in the b-value implies there were significant changes in seismicity over the centuries.

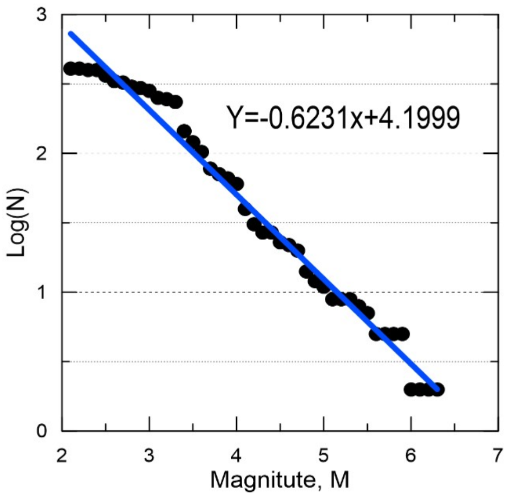

Fig. 4. Sample plot of seismicity when considering events from 1393 till 2020.

3. Conclusions

In this study, an attempt to integrate historical macroseismic data into the modern instrumented database on earthquake events was made. This was to help increase the number of data available for earthquake studies such as seismicity. The regressed a and b-value parameters increased when the data from 2 till 1392 excluded from the consideration. This variation of regressed seismicity parameters suggest more seismicity occurred in the Choseon dynasty than in times before Choseon dynasty.

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