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DETERMINISTIC SEISMIC HAZARD ANALYSIS AND EARTHQUAKE DAMAGES

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Abstract:

Deterministic Seismic Hazard Analysis (DSHA) is a crucial scientific approach that assesses earthquake risks by examining the potential for ground shaking and the resulting damages in specific geographic regions. This article explores DSHA's fundamental principles and its vital role in predicting and mitigating the devastating consequences of earthquakes. By understanding seismic hazards and their impact, policymakers, engineers, and disaster preparedness agencies can make informed decisions to enhance community resilience and minimize earthquake-related damages. DSHA is rooted in the precise evaluation of geological data, historical seismicity, and fault lines. By utilizing this information, experts can model the expected ground motion from a major earthquake event with remarkable accuracy. This predictive ability allows for the identification of vulnerable infrastructure, critical facilities, and at-risk populations. The integration of advanced computational methods, geospatial technologies, and geotechnical engineering principles enables DSHA to provide valuable insights into the seismic vulnerability of structures and infrastructure. Engineers can use this information to design earthquake-resistant buildings and retrofit existing ones, reducing the potential for damage and loss of life during a seismic event. DSHA is instrumental in shaping building codes and land-use planning regulations. It ensures that construction practices in seismically active regions adhere to stringent safety standards, ultimately safeguarding lives and property.

Key words: *Seismic Hazard Analysis, Earthquake Damage Assessment, Ground Shaking, Seismic Risk Mitigation, Building Codes and Regulations*

Introduction

One of the active segments that makes up the Sumatran Fault Zone (SFZ) is called the Siulak fault . These fault zones, which are connected with the Cenozoic Period and have a length of 1,650 kilometers for a dextral strikeslip fault zone, are responsible for accommodating a portion of the oblique convergence of the subduction that occurs between the Indo-Australian and Eurasian plates. The section travels through regencies, the former of which is a valley that has been filled with volcanic debris other nearby volcanoes. In 2010, a magnitude seven earthquake rocked this region, causing the ground to shake and causing the deaths of about 84 people and the destruction of 17,670 homes. The seismic activity in this region was validated by later seismicity as being an earthquake that took place in 2005. Because it is believed that this region is still capable of producing earthquakes, and because the strong ground shaking that may be generated by earthquakes can result in a large number of deaths, it is imperative that a seismic hazard assessment be carried out in this region in order to forecast the ground motion that will be induced by prospective earthquakes in the future. Using seismological data and a method called deterministic seismic hazard analysis (DSHA), which has already been successful in mapping seismic danger in various areas, the current study aims to derive the ground motion value over the region being investigated. The seismicity catalogues that are available, geological data, and a scenario involving one or more earthquakes are utilized to estimate the ground motion value across the area that is being researched. In order to give information for decision-making about earthquake mitigation, land use, and infrastructure, it is necessary to have a knowledge of ground motion as it relates to seismic occurrences. We anticipate that architects and engineers will be able to utilize our findings to enhance the design and construction of buildings by taking seismic design maps into consideration.

EARTHQUAKE PREDICTION

"There are some occurrences that are completely out of the blue, and no one can be ready for them." In spite of the fact that damaging earthquakes cannot yet be predicted with absolute precision, intermediate-term (i.e. several months scale) and middlerange (i.e. few hundred kilometers scale) predictions of main shocks above a pre-assigned threshold (based on seismicity "alarms" generated by interpretive algorithms like CN and M8) (ICTP Report 2010, 2011) may be appropriately used for the implementation of low-key preventive safety actions, as recommended by UNESCO in 2010 The correct integration of seismological and geodetic information together has now been shown to reliably contribute to a reduction in the geographic extent of CN and M8 alarms and it also defines a new paradigm for time-dependent hazard scenarios. This was demonstrated through the 2010–2013 Seismic Crisis in Central Italy and the 2012 Emilia earthquake sequence. Within this supporting framework, GPS data are utilized to reconstruct the station velocities and strain patterns along pre-selected transects. These transects are correctly oriented in accordance with information on the known tectonic settings. In general, experience has shown that analyses of the available geodetic data (highlighting both ground velocity variations and related strain accumulations within the areas alarmed by CN and M8) can permit significant reductions of their sizes and extents This is very encouraging news! A first attempt at earthquake prediction was made a few years ago within the framework of Project SISMA (SISMA-ASI, 2009, 2010), which was funded by the Italian Space Agency (ASI). The purpose of this project was to jointly use: (i) seismological tools (such as the CN algorithm and scenario earthquakes); and (ii) geodetic methods and techniques (such as GPS and SAR monitoring) to effectively identify and constrain priority areas where prevention and seismic risk mitigation measures should be concentrated. In the instance of the Seismic Crisis that started in Central Italy on August 24, 2010, with the M 6.1 Amatrice earthquake, a further refinement of this extremely productive integration of seismological and geodetic information has been implemented. This integration of information has shown to be very fruitful. In contrast to the much more typical method, GPS data are not used in this study to estimate the standard two-dimensional ground velocity and strain fields in the region. Instead, these data are used to reconstruct the velocity and strain patterns along specifically chosen transects, which are correctly oriented according to a priori information about the known main regional tectonic settings. This approach differs significantly from the more typical method in several important respects. Independent verification of the accuracy of the GPS station findings are performed using the SAR data related to the coseismic displacements caused. An overall examination of the available geodetic data reveals that, in the case of the event, it is now feasible to emphasize both the velocity variation and also the accompanying strain buildup in an area of around just 5000 km2, which is within the region that has been monitored here by CN since November 1, 2012. The counter instances that were evaluated, which were spread over alerted and non-alarmed regions of the CN, did not reveal any spatial accelerations along localized patterns equivalent to the one that is well-defined along the transect. In the case of the earthquake that occurred in Emilia in 2012, researchers from Peresan et al. (2010) came to similar results after taking into account the stress pattern of the study region.

Deterministic Seismic Hazard Analysis (DSHA)

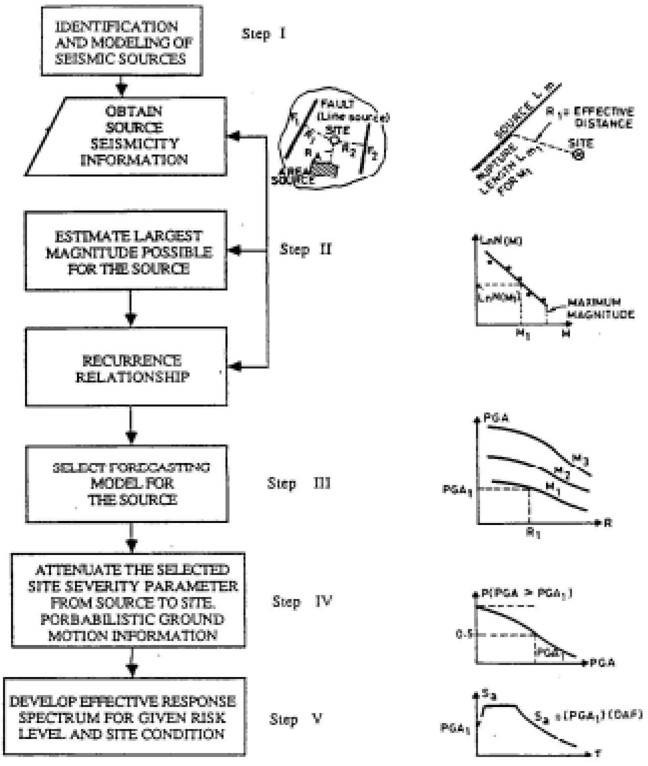
Two types of seismic hazard analysis that have been popular in recent years are the deterministic seismic hazard analysis (DSHA) and the probabilistic seismic hazard analysis (PSHA). DSHA were looked into rather than anything else during this investigation. The primary purpose of this investigation was to uncover a worst-case scenario for a severe seismic hazard in the region that was being researched as an engineering consideration to unexpected earthquake occurrences. The Determination of Expected Maximum Magnitude or Maximum Credible Earthquake that

May Occur is Required by DSHA. This will help determine which earthquake poses the greatest threat to the location. An empirical strong ground motion attenuation model is used whenever there is a need to analyze ground shaking at a specific location. The distance from the source to the place with the lowest travel time is then chosen, and the worst-case scenarios for each area are analyzed. The analysis relied on the assumption of the worst possible scenario for each earthquake source, which provided information on the most severe degree of seismic hazard that may have happened. established DSHA as a concept for the purpose of constructing essential structures with attention given to PGA on site. Examples of such facilities are nuclear power plants and big dams. In addition to this, the DSHA restriction that does not take into account the unpredictability and possibility of earthquakes occurring across the researched region needs to be taken into consideration.

PROBABILISTIC SEISMIC HAZARD ANALYSIS

In the past 20 to 30 years, the use of probabilistic concepts has made it possible for uncertainties in the size, location, and rate of recurrence of earthquakes as well as the variation of ground motion characteristics with earthquake size and location to be explicitly considered in the process of evaluating seismic hazards. This has allowed for a more accurate assessment of the potential dangers posed by earthquakes. The probabilistic seismic hazard analysis, also known as PSHA, is a framework that gives a more full view of the seismic hazard by allowing these uncertainties to be recognized, quantified, and merged in a logical manner. The DSHA procedure may also be defined as a technique consisting of four steps, each of which has some degree of resemblance to the steps of the PSHA procedure (Reiter, 2006). The PSHA procedure can also be described as a procedure consisting of four steps:

1. Identification and characterization of earthquake sources is the first stage, which is the same as the first step of the DSHA. The only difference is that the probability distribution of probable rupture locations inside the source must also be described. The vast majority of the time, uniform probability distributions are assigned to each source zone. This indicates that earthquakes are just as likely to occur at any place inside the source zone as they are everywhere else. The relevant probability distribution of source-to-site distance is then obtained by combining these distributions with the source geometry.
2. The seismicity, also known as the temporal distribution of earthquake recurrence, is the next thing that has to be defined. A recurrence relationship, which describes the average rate at which an earthquake of given size will be surpassed, is used to characterize the seismicity of each source zone. This relationship indicates the magnitude of the earthquake that will be exceeded. The recurrence relationship could be able to account for the largest earthquake ever recorded, but it does not restrict attention to just that quake like DSHAs often do.



Schematic Illustration and Flow C..art of Probabilistic Seismic Hazard Analysis (PSHA)

3. Utilizing predictive connections, one must ascertain the ground motion generated at the site by earthquakes of each conceivable magnitude happening at any conceivable place in each source zone. This motion can be caused by any earthquake. A PSHA takes into account, among other things, the inherent unpredictability of the prediction connection.
4. In the end, the uncertainties in earthquake location, earthquake magnitude, and prediction of ground motion parameter are combined to arrive at the likelihood that the ground motion parameter will be surpassed during a specific time period. This probability is then presented as a percentage.

IDENTIFICATION AND EVALUATION OF EARTHQUAKE SOURCES

In order to evaluate the seismic risks associated with a certain location or region, it is necessary to first identify all of the potential sources of seismic activity and then assess each source's ability to generate future strong ground motion. A seismic source is, by definition, the location in the crust of the earth in which it is anticipated that future seismicity will follow a given probability distribution of occurrence in time, space, and earthquake magnitude. This distribution may be broken down into three different dimensions: time, space, and earthquake size. In order to correctly identify the origins of seismic activity, one must take into account not only the geology and tectonic data but also the historical and instrumental seismicity.

Geologic and Tectonic Evidence

According to the idea of plate tectonics, evidence of earthquakes may be found in the geologic record, mostly in the form of offsets, which can be thought of as relative displacements of different strata. This provides us with reassurance that earthquakes have occurred in the past. According to plate tectonics and the elastic rebound theory, earthquakes take place to release the strain energy that builds up when plates move in relation to one another and cause friction between them. According to Smith (2010), the pace of movement need to be connected to the rate of strain energy buildup as well as the rate of strain energy release. The determination of seismic sources based on geologic data is an essential component of seismic hazard assessments, despite the fact that it is sometimes challenging. The localization of faults is the primary focus of investigations looking for geological evidence of earthquake origins.

Fault Activity

However, the sheer existence of a fault is not sufficient evidence to conclude that there will be earthquakes in the future. The concept of fault activity is significant, and it has been the subject of a great deal of debate and argument over the course of recent history. Although there is widespread consensus over the use of the words "active fault" to describe a fault that is now at risk of producing an earthquake and "inactive fault" to describe a fault on which earthquake activity has occurred in the past but is not expected to do so again, there is one exception to this rule.

Magnitude Indicators

Geologic evidence may also be used to estimate the magnitude of prior earthquakes by connecting the observable properties of deformation with the known magnitudes of recorded earthquakes. This method is known as the correlation method. Field geological studies conducted after an earthquake can be used to determine the fault's displacement, as well as the length and size of the rupture. The correlation of magnitude with such quantities requires regression on restricted data sets and, as a result, generates an estimate of the value that one would anticipate the magnitude to have.

Historical Seismicity

Records of seismic activity throughout history can also be used to locate the causes of earthquakes. In the United States, the written historical record only goes back a few hundred years, or perhaps fewer. However, in Japan and the Middle East, the recorded historical record may go back as far as 2,000 or even 3,000 years. The utilization of historical descriptions of ground-shaking impacts may be utilized to both corroborate the existence of earthquakes in the past and to estimate the geographical distributions of the strength of such earthquakes.

Instrumental Seismicity

In the last eighty or ninety years, there have been around ten earthquakes of magnitudes greater than seven that have occurred somewhere in the world each year. Instrumental recordings of significant earthquakes have been accessible since around the year 1900, despite the fact that many records from before 1960 are either insufficient or of variable quality. Nevertheless, instrumental recordings are the greatest available evidence for determining the origins of earthquakes and analyzing this information. The very short amount of time during which they have been accessible, in comparison to the typical amount of time that passes in the intervals between major earthquakes, is their most important constraint.

Data and Method

In the Kerinci and Sungai Penuh regency, a deterministic seismic hazard analysis was utilized in order to anticipate the maximum ground motion. When trying to anticipate ground motion, the typical DSHA is connected with a single controlling seismic source. The ground motion will be described in terms of the peak ground acceleration (PGA) and the spectral acceleration (SA) for 0.1 seconds, 1.0 seconds, and 3.0 seconds, respectively. We utilized the MMI scale, which is based on Worden classifications, in order to define this region of interest in terms of the intensity that is associated to seismic occurrences. From the data in the earthquake catalog located in the area of interest, we were able to gather the characteristics necessary to assess the potential for earthquakes. In this particular investigation, the earthquake scenario of Mw 7.0 at 10 km depth in 1995 is considered. The PGA was calculated using a shake map created by the USGS. on the meanwhile, the data on the timed-averaged shear-wave velocity to 30 meters depth (Vs30) that was obtained from the USGS is being disseminated on a map to corroborate the results of DSHA.

Result and Discussion

Seismic risks measured in peak ground acceleration, abbreviated as PGA. As can be seen from the PGA map in Figure 4a, the values decrease as one moves outside from the center of the globe. Due to the fact that these statistics do not take into account the activity rate of earthquake occurrence, it suggests that there is an exceptionally high danger level along the active fault zones. The diagram makes it quite evident that the core region, on which the active fault was laid out, is more vulnerable to greater levels of seismic risk. PGA is projected to range from 16 gal in most of the locations that are far away from the Siulak faults to 71.9 gal beside the active faults (Fig. 4a). A seismic hazard can be described using an intensity level, which can be converted from PGA. MMI levels may be used to provide a description of the intensity of these areas, which is useful for illustrating the kinds of possible damage that could be caused by an earthquake occurrence. According to the MMI level, it was discovered that regency were between VI and VIII. The possibility for injury ranges from very little to a fair amount . It is expected that areas with PGA values between 16 and 22 gal would have mild possible damage, while those with PGA values between 22 and 45 gal will experience moderate potential damage. Within the range of 45-71.9 gal in terms of PGA, there is the possibility of severe to heavy damage being caused. The places most at risk for earthquakes are located in the middle to eastern parts of Kayuaro Barat; the middle of Gunung Kerinci, Siulak, and Bukit Kerman; the northern part of Gunung Raya; the western parts of Kayuaro, Danau Kerinci, Air Hangat Timur, and Sitinjau Laut; and the eastern parts of Air Hangat Barat, Sungai Penuh, Depati Tujuh, and Keliling Danau. On the other hand, practically every side of the district that is far from the Siulak fault has a low potential for seismic activity (Batang Merangin, Gunung Tujuh, the western side of Sungai Penuh, the eastern side of Siulak Mukai and Air Hangat, and so on). As a significant center of activity, Sungai Penuh is predominately located in seismic zone VII, which is where the majority of the PGA value ranges from 22 gal to 40 gal. This zone is dominated by the region. The PGA value drops from east to west of the Sungai Penuh river, which indicates an increasing seismic risk in this location. Contrasting PGA range values may be seen in the area to the east of Sungai Penuh and at the southwesternmost tip of the region. It appears that the eastern region is located in seismic zone VIII, which has PGA values ranging from 40 to 71 gal, while the southeasternmost tip of the region is located in seismic zone VII.

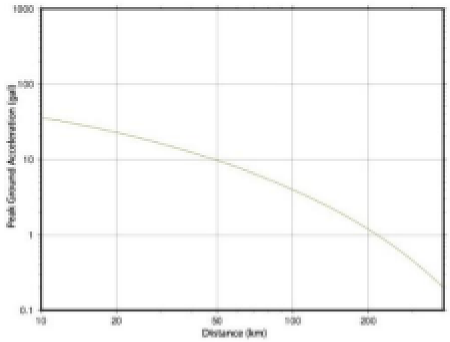


Figure 3. Hazard curves plot between PGA values (gal) vs distance from earthquake source (km). It reveals the distance contribution to PGA value distribution by DSHA.

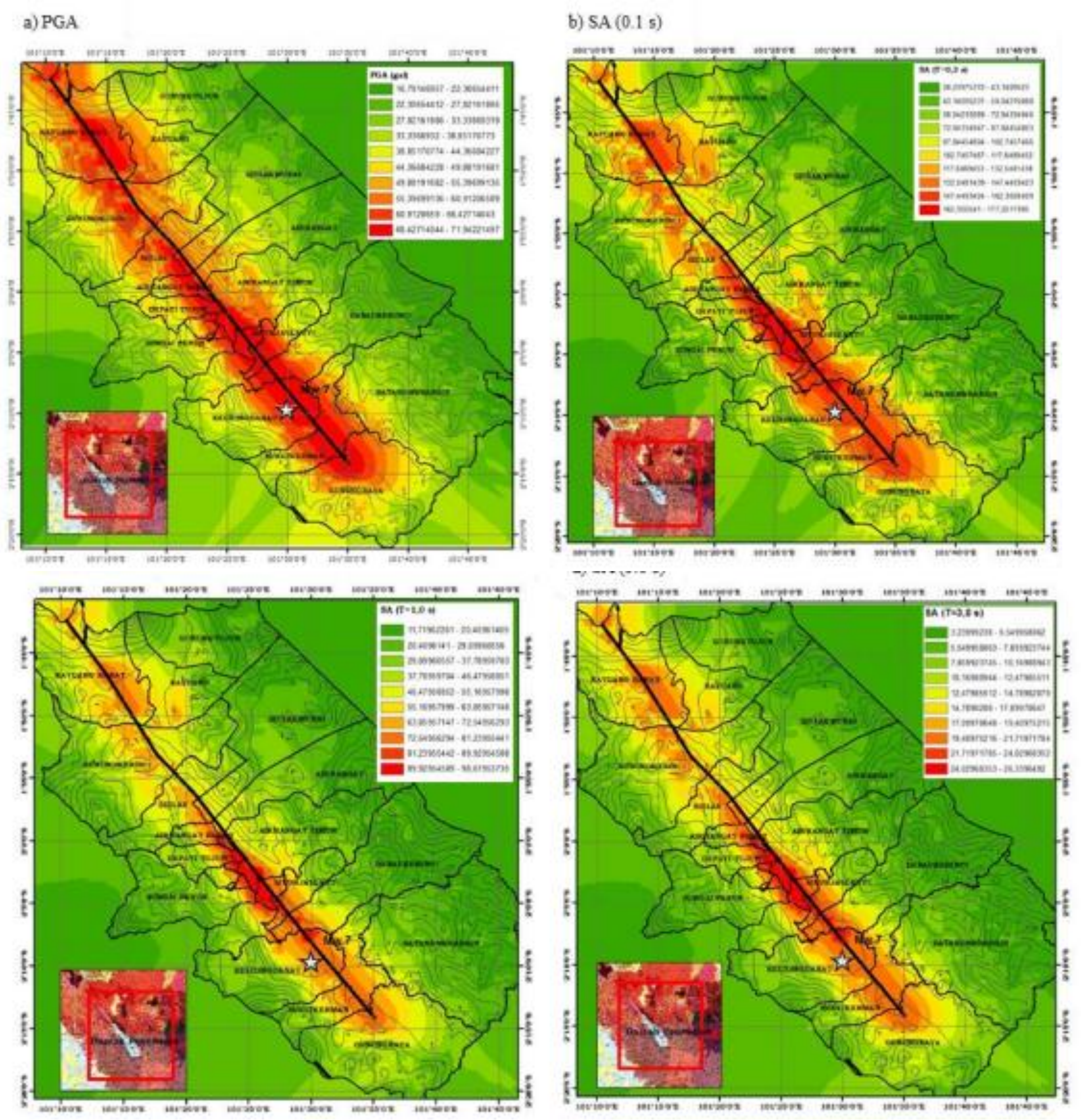


Figure 4. Maps showing of PGA, SA 0.1 s, SA 1.0 s, and SA 3.0 relative contribution from event of Mw 7.0 from Siulak fault, respectively. White star denotes source of event.

the seismic zone VI, which ranges from 16 to 22 gal in PGA value. It has been determined that the Siulak fault segment was the source that contributed to the high PGA values found in this region. The same pattern was observed in the 2011 Peta Bahaya Gempa Indonesia survey as well. The hazard curves in terms of PGA vs distance from the earthquake source are presented in Figure 3. These curves make it abundantly evident that the risks in the center region are the highest, followed by the areas that are next to the core area. The curve gives information on distance parameters, which play a significant role in determining the PGA value that is produced by DSHA. The data obtained from the danger curve is incorporated into each and every one of DSHA's maps. In spite of the fact that the SA values vary, all of the SA maps display the same trend, which is that the SA values gradually drop from the Siulak fault to the surrounding region cover up (Fig. 4b, 4c, 4d). The primary purpose of SA maps is for engineering consideration. Again, larger values were recorded for regions near the Siulak fault because of their proximity to the seismically active region of Sumatra. This proximity likely accounts for the higher values. For the sake of this study, it is important to stress that these dangers are estimated using the most catastrophic possible scenario for the Siulak fault source.

Conclusions

This study gives an overall SHA measured in terms of PGA for the regencies using DSHA. The paper also models historical point sources. There is a high degree of congruence between the prospective seismic hazard and the Vs30 distribution along the fault zone. According to the DSHA's critical case scenario, the hazard over regency in terms of PGA varies from 16 to 71.9 gal, with the largest PGA occurring in locations across the fault. This was determined by analyzing the data for the critical case scenario. In a similar vein, the SA maps demonstrated that the response is at its peak at the fault. However, it is important to note that the current study concentrated solely on PGA and SA results without taking into account soil amplification and site effect, which may have contributed to an inaccurate estimate. In order to provide the most accurate analysis possible when mapping seismic hazard, it is considered important for this region to combine at least one approach that can forecast seismic hazard.

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