SEISMIC RISK STUDY OF JEDDAH REGION IN SAUDI ARABIA

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SUMMARY

Several geophysical observations and studies indicate that, contrary to the popular belief, the western part of Saudi Arabia is an active seismic region. This paper presents probabilistic estimates of the earthquake intensities to be expected in Jeddah region situated in the western central part of Saudi Arabia. The study is based primarily upon the historic seismic records. The geology of this region and the distribution of faults is not completely known and is used only to a minor extent in this work.

INTRODUCTION

There is direct evidence relating to the potential seismic risk in Western Saudi Arabia reported by investigators. Poirier and Taher (Ref.1) compiled a catalog of historical seismicity from the VIIth to the XVIIIth century A.D. from Arabic documents for the Middle East. They have reported a series of earthquakes of intensity VI to IX in various parts of this region. In the more recent past, Gutenberg and Richter (Ref.2) reported an earthquake that occured on January 11, 1941 at about 30 km to the east of the city of Jizan and near the town of Abu Arish. The magnitude of the event was about 6.25. Rothe (Ref.3) also reported an earthquake that occured on October 17, 1965 near the Saudi Yemeni border, to the east of Abu Arish, of magnitude 5.5. As recent as Decembr 1982, there was an earthquake of magnitude 4 to 5 in North Yemen which caused devastating damage in the area.

A complete catalog of all earthquake events for this region for the period 1906-1978 is available from the International Seismological Center at Berkshire, England and the earthquake data from April 1752 to December 1978 is available from the Institute of Geological Sciences at Edinburg, Scotland. The data from these two sources has been utilized in the seismic risk study presented in this paper.

SEISMIC SOURCE MODELING

The general principle used in determining the seismic risk for a region is that future earthquake occurrences are assumed to have the same general average time rate characteristics as the earthquakes of the past. It is further assumed that future earthquakes in a particular area may occur over somewhat more extended area than indicated by historical data. In this study, line sources are used to model the seismicity of Western Saudi Arabia.

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Pertinent Geological Faults

Knowledge on the existence and the activity of all geological faults in Saudi Arabia is incomplete, to say the least. For this study only macro information is needed, thus, only major faults and faults that have shown recent activity are considered. Ref.4 was used for the location of faults and their activity in the Red Sea. Ref.5 was utilized for the location of faults in the coastal plain in Western Saudi Arabia.

It is generally believed that Arabia separated from Africa in a northeasterly direction, and in the process several transform faults trending in this direction may have been formed (Ref. 6). Seismic events recorded in the area of study reveal a consistent but incomplete pattern relating to rifting. Most of the epicenters are along the axial trough of the Red Sea and are shallow (< 100 km).

Seismic Sources

Most of the faults considered are modeled by line sources which are taken as closely as possible to the actual faults. Based on the location and behaviour of faults and the geographic distribution of past earthquakes, 14 line sources are established as shown in Figure 1. The past earthquakes are then sorted according to each source assuming that all earthquakes originate on a particular source. A band is drawn around each source and all the epicenters within that band are attributed to it.

The number of earthquakes attributed to each source is listed in Table 1. The table also shows the largest Richter Magnitude that can occur on any source (M_{max}-assigned), the largest Richter Magnitude ever recorded on each source (M_{max}- recorded) and the focal depth for each source.

Table 1 Number of earthquakes attributed to each source.

Source No.	Number of Records.	M_{max} (Assigned)	M_{max} (Recorded)	Focal Depth (kM)
1	33	6.44	6.80	33
2	2	6.00	6.00	0
3	2	5.00	5.00	33
4	5	5.48	5.00	33
5	35	7.32	5.90	64
6	8	5.46	5.75	33
7	13	7.33	6.75	33
8	15	6.22	5.60	33
9	3	6.04	6.20	0
10	7	7.02	5.70	41
11	51	7.14	6.10	33
12	6	6.82	5.44	15
13	5	6.00	5.00	0
14	7	6.00	5.00	0

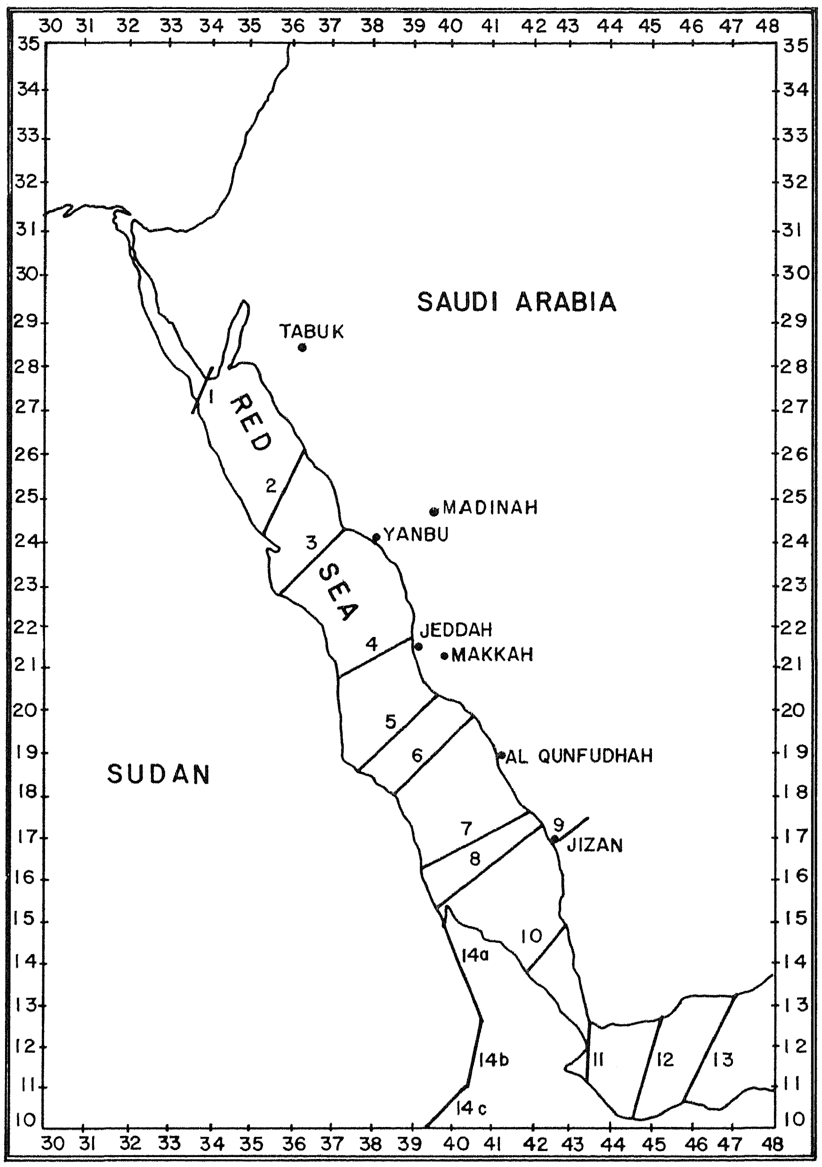

Figure 1: Seismic Sources

Recurrence Relationships

The log-linear Richter's recurrence relationship is used to determine the frequency characteristics for the model, i.e.,

$$\log N = a - bM \tag{1}$$

For each of the sources defined, the log-linear recurrence equation is obtained through regression analysis of the sorted data. The value of the intercept 'a' varies from 1.008 to 3.593 and the slope 'b' varies from 0.1 to 0.5338 for various sources.

SEISMIC RISK MODEL

The seismic risk model used in this study is based on a method which produces relationships between such ground motion parameters as Modified Mercalli Intensity or peak ground acceleration and their average return period for a given site. Based on this method, a FORTRAN computer program for seismic risk analysis has been developed by the United States Geological Survey (Ref.7) which is used in the seismic risk analysis in this paper. The method is based on integrating the individual influences of potential earthquake sources, near and far, more active or less, into the probability distribution of maximum annual intensity (Ref.8)

$$P\{A\} = \int \int P\ \{A/S \text{ and } r\}\ f_S\ (s)\ f_R\ (r)\ ds\ dr \tag{2}$$

where P indicates probability, A represents event that a specific value of ground motion intensity is exceeded at the site during an earthquake, variables s and r represent earthquake size (magnitude or epicentral Modified Mercalli intensity) and distance respectively from the site of interest. Once the risk associated with an intensity level i at a site has been calculated for the occurrence of one earthquake of arbitrary magnitude and location in a source, the annual expected number of events from that source is obtained by multiplying the single event risk by the expected number of events during one year. The total expected number of events causing intensity $I \geq i$ at the site is obtained by summing the expected number from each source. Risks are then calculated assuming that earthquakes occur as Poisson arrivals, that is,

$$\text{risk} = 1 - \exp\ (-\ \text{total expected number}) \tag{3}$$

SEISMIC RISK RESULTS

All the information discussed in this report is synthesized to obtain the seismic risk for Jeddah. Figure 2 shows the cumulative distribution function (Ref.9) for 100 years of future time. It shows that the probability that intensity 5 will be exceeded in 100 years at Jeddah is 0.15. Alternatively, the intensity is 4.5 at Jeddah for 50% chance of exceedence. Another item of interest is the intensity zone graph (Ref.10) shown in Figure 3. As an

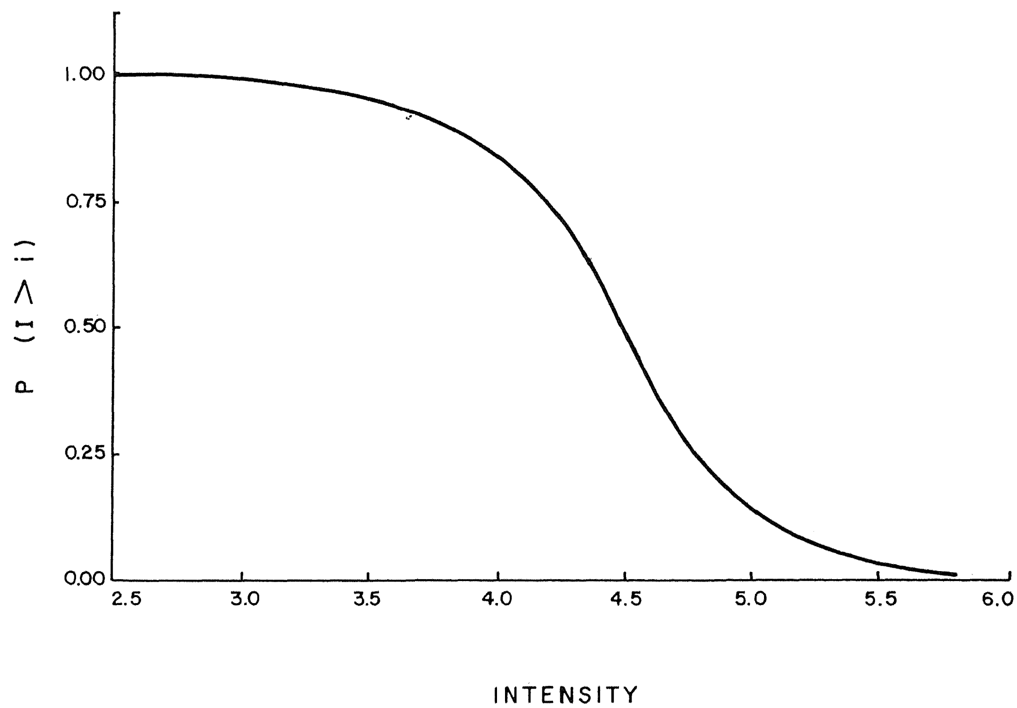

Figure 2: Cumulative Distribution Function

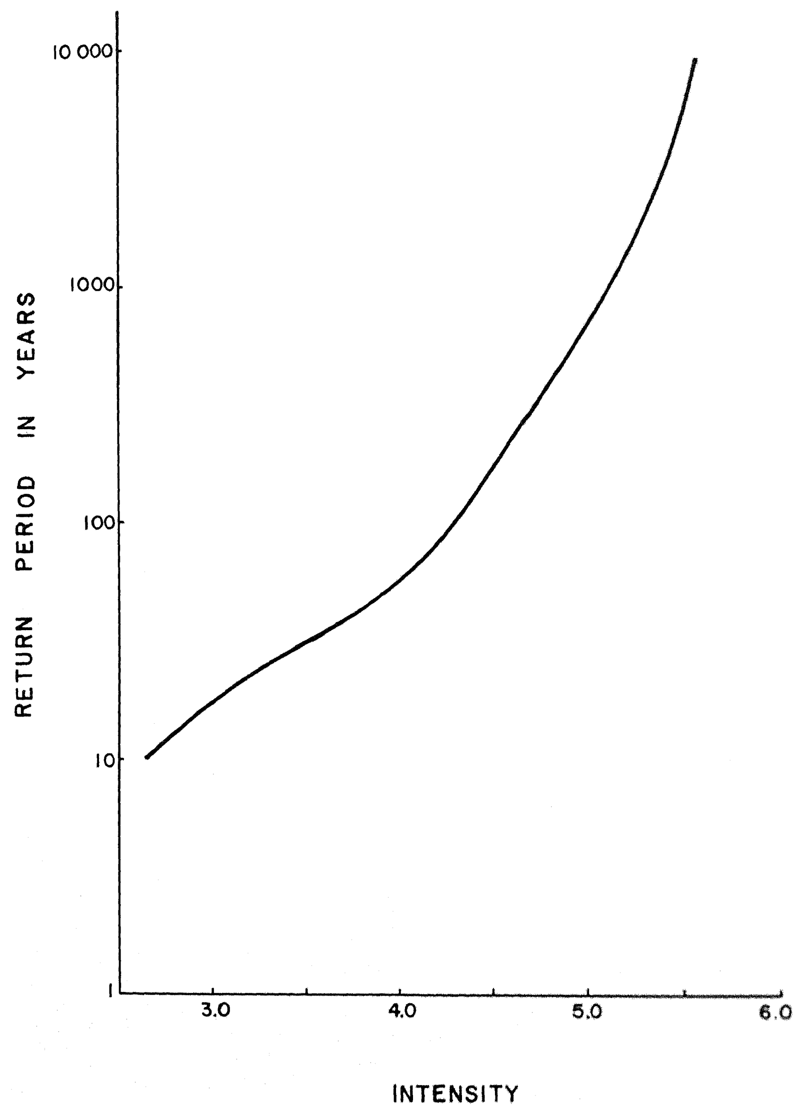

Figure 3: Intensity Zone Graph

example, for an intensity value of 4, the corresponding return period is 52 years.

A relationship of interest to structural design engineers is the correlation between economic life, return period and risk level. They are related by the equation

$$P (I > i) = 1 - \exp (- T/T_y) \qquad (4)$$

where T = useful economic life
T_y = return period.

As an example, suppose that a light industrial building has to be designed. If the economic life is 50 years, and the acceptable probability of exceeding a damage level is 20% during those 50 years, then from Equation (4), the design return period is 224 years (i.e., 1/224 probability of exceeding a damage level per year). If this structure is located in Jeddah, the design intensity is 4.65 which corresponds to a design accelation of .011 g.

CONCLUSIONS

Several investigators have stated that the Western coast of Saudi Arabia is an active tectonic region and have stressed the need for a seismic risk study of the region. Merghelani (Ref.11) conducted microearthquate monitoring in Jeddah area and contradicted the assumption that Saudi Arabia is seismically inactive.

In spite of the indications about the seismic activity in Western Saudi Arabia, there has been very little work on a detailed study of the seismic risk in the region. The seismic risk results presented and discussed in this paper contain information on probability of exceeding given intensity levels, return periods of events and future exposure time, all of which give value information for engineering purposes.

ACKNOWLEDGEMENT

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