# AN ENGINEERING SEISMOLOGICAL STUDY ON THE 1976 ÇALDIRAN EARTHQUAKE IN TURKEY

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## SYNOPSIS

The Çaldıran earthquake gave a unique opportunity to attack an elucidation of the total feature from seismic source process to spatial damage distribution. A joint research group between Turkey and Japan was organized and a detailed investigation has been continued.

By use of the seismological and field experimental data, a model for seismic intensity analysis, taking consideration into finiteness of earthquake fault, slip distribution, and site geology was applied to this earthquake. Superiority of this new model was clearly demonstrated by comparison between the observed and calculated intensities. The most probable source parameters, which are determined by a sensitivity analysis of the new model, show quite an agreement with those estimated by the WWSSN data.

A disaster analysis, combined loss of human lives with structural damage, was also performed in the similar manner. Calculated composite damage ratio are highly correlated with the observed values. Engineering seismological significance of the new model was also discussed.

## INTRODUCTION

Although there have been many reports on seismic disasters, no systematic study which considers all the influential factors such as seismic source process, wave path and site geological effects is appeared.

The recent Çaldıran earthquake, a typical inland and shallow large earthquake, provides us the best situation to persue this subject, since the whole feature of a newly made fault and structural and other damages in the shocked area can be clarified through field surveys. Besides, the seismic records essentially important for the source mechanical solution are also available by the world-wide standardized network.

Between Turkish and Japanese researchers who realized the engineering seismological importance of making a study of the Çaldiran earthquake, a joint research group was organized and an energetic investigation has been continued including several times of field surveys.

In this paper, after a brief description about the general characters of this earthquake, studies on seismic intensity analysis and structural damage evaluation coupled with loss of human lives are mainly reported with an introduction of a new model.

## EARTHQUAKE

The Çaldiran earthquake occurred at 14 h 22 m local time on Nov.24, 1976 shaked a wide area in eastern Turkey and carried off about 4000 lives and injured 500 persons. The damaged houses beyond repair were close upon 10000 in number. The magnitudes reported are Ms=7.1, ML=7.6, and Mb=6.9. And the epicenter is about 100 km east of the junction between north and east Anatolian fault lines. The maximum intensity observed was IX(MSK) at

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Çaldıran. For the focal depth, the instrumental observation indicates 40-60 km, but the field evidences suggest a shallower depth (Table 1). A series of fault breakages appeared in the N70°W direction (Fig.1).

Immediately after the earthquake occurrence a field survey was performed by the Turkish Earthquake Research Institute, and an excellent quick report has been published (1977).

## INTENSITY ANALYSIS

The isoseismal map in the MSK scale, referred in Fig.2, characterizes that the isoseismals show no symmetricities in both axes along and across the fault line. The seismological information suggest that the fault surface may tilt westwards, slip vectors are different along the fault line. Furthermore, site geology changes from place to place.

The intensity evaluation should take consideration of all the above features. To take account for the fault length, width and dip, slips on the fault surface, and distance from the fault, may not be impossible, since all of them are numerically expressible. However, simultaneous consideration of such metric variates with non metric variate as site geology is beyond the empirical equations proposed in the past. What we examined was an application of the quantification theory developed by Hayashi (1961).

*Model* The idea is that the intensity at a site is determined as the total contribution of the slips distributed on the fault surface plus site geological effect. Let us define the coordinate-systems as shown in Fig.3. The fault surface with length L and width W is expressed in terms of $(\xi,\eta)$ coordinates. Angle between y- and $\eta$- axes is $\theta$, equal to the tilt of the fault surface. $D(\xi,\eta)$ represents the averaged slip in a small area $d\xi d\eta$. Let us suppose that the seismic strength (effective acceleration) affected by the segmental area can be written at (x,y) as

$$da = \text{const.}\frac{D(\xi,\eta)d\xi d\eta}{r^p}, \text{ where } r=[(x-\xi)^2+(y-\eta\cos\theta)^2+(\eta\sin\theta)^2]^{1/2}$$

Then the total contribution of the whole fault surface is easily as

$$a(x,y) = \text{const.}\int_0^L d\xi\int_0^W \frac{D(\xi,\eta)d\eta}{r^p}$$

In case of $D(\xi,\eta)=D(\xi)$, the above equation changes to

$$a(x,y) = \text{const.}\int_0^L D(\xi)d\xi\int_0^W \frac{d\eta}{r^p} \qquad (1)$$

The slip data by the field survey is usually $D(\xi)$ instead of $D(\xi,\eta)$. Therefore Eq.(1) is most appropriate for our investigation. Here, let us rewrite Eq.(1) as $a(x,y) = c\,A(x,y;p)$ and assume $A(x,y;p)$ is evaluated by knowing the fault configuration and the slip distribution, leaving a parameter p undetermined. Now, the most common transform of acceleration to seismic intensity is a form of $I = \alpha \log a + \beta$, therefore,

$$I = c_1 \log A(x,y;p) + c_2.$$

Next, let us introduce site geological effect by assuming soil types classified into m groups such as soft, intermediate, and hard rocks, then

$$I(x,y) = c \log A(x,y;p) + \sum_{j=1}^{m} Zj\delta(j) \qquad (2)$$