Investigation of destructive and non-destructive aftershocks in important earthquakes

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Abstract: One main factor that is taken into consideration during the occurrence of a large earthquake is related to the aftershocks, which cause considerable damage in terms of excessive losses of precious human lives and valuable property. The importance of large aftershocks is considerable, since buildings that have suffered damage during the first earthquake and have not been vacated by residents would certainly collapse in an aftershock and result in an increased number of fatalities. While the aftershocks could be predicted a few hours after the main earthquake strikes, by taking into account the structural geology of the area (type of fault), the distribution of aftershocks and the trend of variation of magnitude and focal depth, an earthquake with potentially damaging aftershocks could be differentiated from those with a lesser potential for damage (taking into consideration the type of construction in the area).

This research aims at investigating a number of main earthquakes in Iran like those at Bam , Zarand and Kojure and some other significant earthquakes around the world. In this approach , based on shallow distribution of aftershocks and variation of focal depth , studies have revealed that in aftershocks that have a shallow distribution and with a lower and more variable focal depth , larger aftershocks are to be expected.

Résumé: La relation entre les tremblements ulterieurs et les dommages (pertes) corporels et financiers qui en resultent sont les facteurs les plus importants que nous devons prendre en consideration. L'importance des tremblements ulterieurs larges serait plus considerable lorsque les batiments soient vulnerables a la suite du seisme principal d'autant plus que les tremblements ulterieurs larges detruisent les batiments et augmentent ainsi les pertes dont le seisme en est la cause. Alors que quelques heures apres le seisme princpal on a la possibilite de prevoir la grande etendue des tremblements ulterieurs quand on considere la structure geologique de la region (genre de la faille), la distribution geographique des tremblements ulterieurs ainsi que les changements de l'etendue et la profondeur du foyer des tremblements ulterieurs.

Grace a cette methode, un seisme qui a la puissance des tremblements ulterieurs destructifs se distingue des tremblements ulterieurs qui ont le pouvoir de destruction moins vaste (certes par rapport du genre des batiments de la region).

Cette recherche a ete faite sur un certain nombre des principaux seismes en Iran par exemple a Bam, a Zarand, a kajour et sur quelques seismes importants du monde entier. Dans cette methode, on a etudie la distribution de la surface et la variation de la profondeur du foyer des treemblements ulterieurs, car a propos des tremblements ulterieurs dont la distribution de la surface est moins vaste et la profondeur du foyer est plus variee, nous devons attendre les tremblements ulterieurs plus vastes.

Keywords: Earthquakes, collapse, properties, materials, stress, strength

INTRODUCTION

Since aftershocks are very important in terms of the release of energy resulting from the main earthquake and in most earthquakes damage emanating from aftershocks has been significant, many articles have been published in this regard. Frequently, damage resulting from the larger aftershocks are more significant due to the buildings whose structure has been weakened, rather than from the main earthquake itself. Therefore, identification and research regarding destructive and non-destructive aftershocks in controlling and reducing human and financial losses resulting from aftershocks is of considerable importance.

THEME

Subsequent to the occurrence of the main earthquake some of the buildings, which have been weakened but not destroyed altogether and can still be used, are inhabited by residents who continue living in these buildings after the earthquake. Aftershocks, which frequently follow the main earthquake, render considerable damage to these weakened structures. Consequently, the occurrence of big aftershocks leads to the destruction of weak and unstable buildings, which contributes to the loss of human life in the earthquake. In this regard, it is pertinent to mention here the Izmir earthquake in Turkey in 1999 and the Landers earthquake in California, in 1992. Therefore, a precise study about the geological structure of the region, type of infrastructure and the fault plane where the earthquake has occurred, as well as the kind of resultant fault, will greatly affect damage reduction due to earthquakes. However, the outcome of these studies must be declared approximately within 2-10 hours after the main shock, which was carried out following the Zarand earthquake.

As has been mentioned earlier, important and effective factors in the study of aftershocks that can enable us to predict large aftershocks include:

- Type of fault and geological structure of the region;
- Geographical distribution of the aftershocks;
- Variation of focal depth with regard to magnitude.

When accumulated energy is released in the seismic focus, the method of release varies according to the type of fault and geological bedrock. Since in areas where bedrock is homogenous, the energy will be released with greater accumulation (Tavakoli 1996), therefore, in these types of bedrock occurrence of bigger aftershocks can be expected. Besides, in earthquakes with resultant faults of dip-slip accumulation of residual energy will be brought about due to movement of the fault plane in the upper and lower direction at various depths. However, these observations, namely variation of earthquake focal depths in the faults with dip-slip and strike-slip movements, have been thoroughly reviewed by Saket *et al*. (2005).

The reason for the contrast in the distribution of aftershocks of the two earthquakes in Bam and Zarand is the type of movement of the fault. In order to investigate the authenticity of the matter, a comparative study of over twenty other major earthquakes in the world has been conducted with the ultimate conclusion that in earthquakes where resultant faults are pure strike-slip or pure dip-slip, a significant difference exists in the accumulation of aftershocks.

In dip-slip earthquakes, due to vertical *in-situ* movement, the distribution of aftershocks is in a limited area, whereas in strike-slip faults due to the extensive fault movement, the distribution will extend more in length in the area.

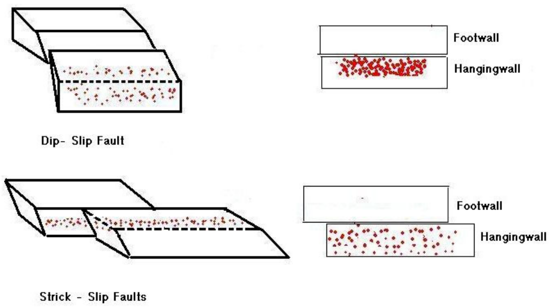

Figure 1. Dip-slip and Strike-slip faults and distribution of aftershocks.

As illustrated in the figure below, the accumulation and variety of aftershocks at different depths can be observed clearly. It is obvious for earthquakes with resultant faults of strike-dip type, distribution of significant aftershocks is at specific and limited depths, while for faults with dip-slip, the focal depth of aftershocks is scattered at different depths down surface of the fault.

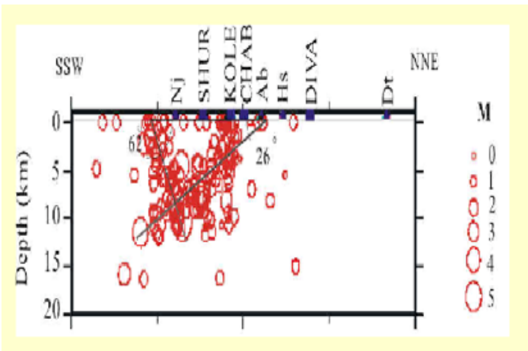

Figure 2. Type of reserve fault that caused the Avaj earthquake in Iran (Hosseini 1381).

Figure 2 shows that aftershocks are distributed at all depths. This specification was for a dip-slip fault.

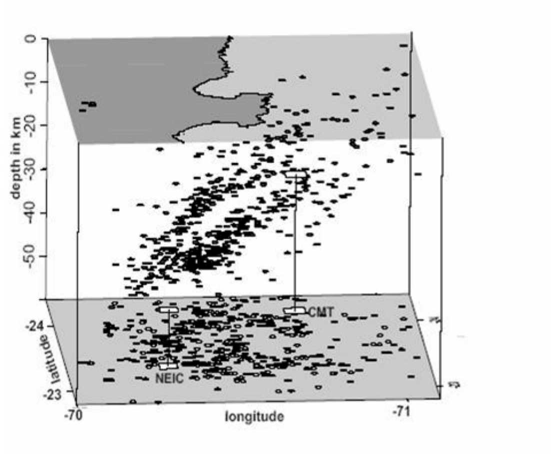

Figure 3 . Aftershocks distribution in Chile earthquake on fault plane (Sobiesiak 2000).

Figure 3 shows that aftershocks are distributed at all depths. This specification was for a dip-slip fault.

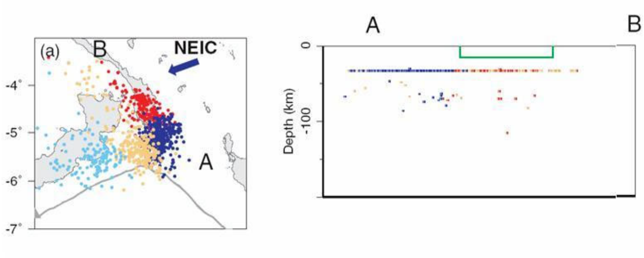

Figure 4. Australia earthquake (Tregoning 2005).

Figure 4 shows that aftershocks are distributed at limit depths. This specification was for a strike-slip fault.

If we compare the earthquakes of Bam and Zarand in this regard, we will notice that the resultant fault of Bam earthquake is strike-dip and in these kinds of faults the distribution of stress will be at limit depth, according to the type of movement. The reduction of energy has been completely gradual and the more we move away from the time of occurrence of the main shock, the more will be the reduction in the size and magnitude of the earthquake aftershocks. However, this condition does not exist in the case of Zarand. Since the stress concentration is at different depths (due to the fault movement at different depths) and taking into consideration the factor that at different depths the effect of upper layer pressure and quality of material of layering is different, so the reaction of different layers against release of residual energy is different and in unspecified periods of time earthquake aftershocks will occur with major and minor magnitudes as well as a number of unspecified earthquakes which are all illustrated in the Figures below.

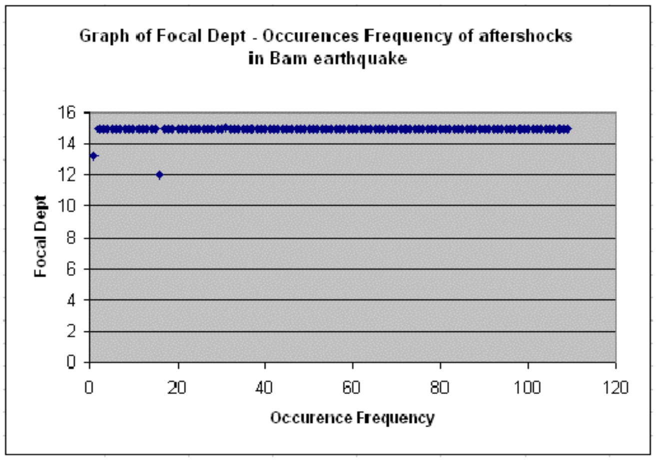

Figure 5. Plot of the "Occurrence frequency" against " Focal depth" of aftershocks from the Bam earthquake.

Figure 5 shows that aftershocks distributed at limited depths. This specification was for a strike-slip fault (Saket *et al*. 2005).

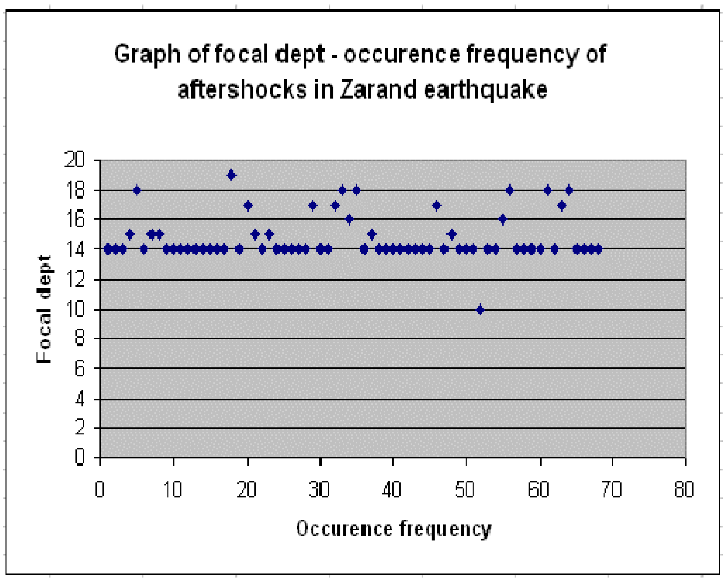

Figure 6. Plot of "Occurrence frequency" against "Focal depth" of aftershocks from the Zarand earthquake (Saket *et al*. 2005).

Figure 6 shows that aftershocks are distributed at various depths. This specification was for a dip-slip fault.

In the figures below, notice the concentration in the number of aftershocks for the two Bam and Zarand earthquakes and the reduction of aftershocks magnitude by moving away from the time of occurrence of the earthquake. It is clear that the Zarand earthquake was more irregular than the Bam earthquake.

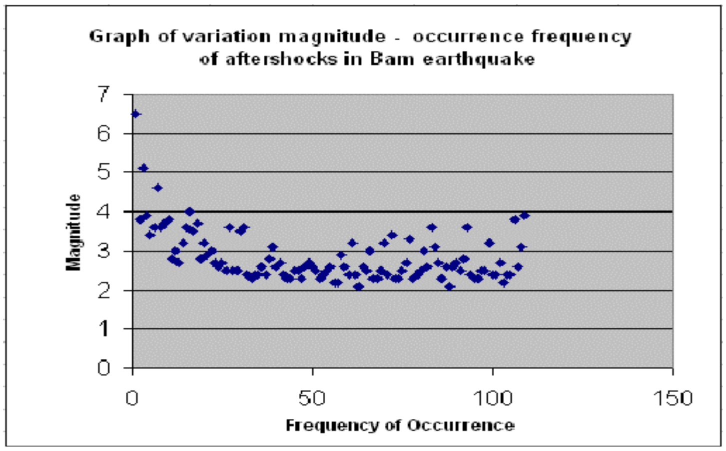

Figure 7. Plot of "Magnitude" against "Occurrence frequency" of aftershocks from the Bam earthquake (Saket *et al*. 2005).

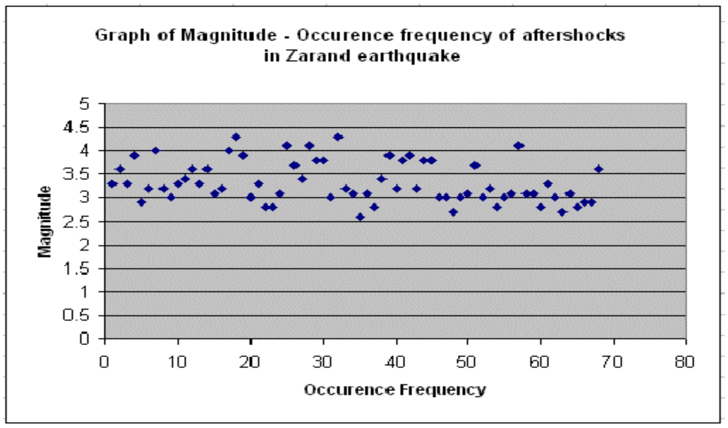

Figure 8. Plot of "Magnitude" against "Occurrence frequency" of aftershocks from the Zarand earthquake (Saket *et al*. 2005) .

Keeping in view this information on aftershocks, if within the first few hours the depth and magnitude of aftershocks changes in an unspecified manner and does not have a specified trend, one can predict that in the coming days, weeks and months the likelihood of occurrence of big aftershocks exists. However, the approximate time of large-scale aftershocks can be predicted only through an accurate and precise investigation.

CONCLUSIONS

Due to their unstable condition in the wake of major earthquakes, buildings are prone to risks and hazards; unfortunately, because most of these damaged buildings are still in use by residents. It is necessary to conduct a precise study including identification of magnitude variations, focal depths, surface distribution of aftershocks. In this way it is possible to predict the destructive number of aftershocks, and their magnitude. In light of this study, we come to the conclusion that aftershocks of earthquakes that are distinguished by their greater depth variations will be destructive, the majority of which are coupled with dip-slip faults.

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