DETERMINATION OF GROUND SURFAEC DEFLECTION DUE TO EARTHQUAKE BASED ON FIELD DATA

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1. INTRODUCTION

Unlike ground vibrations due to earthquakes, no design considers the ground movements due to fault slip. Recent earthquakes provided lots of examples of ground surface deformation causing damages on buildings, roads and lifelines. Therefore, knowledge on measurement of fault deformation is necessary and some effective evaluation methods should be developed. In the past, some studies have been done based on field data. For example Zhang et al. (1999) compared the total rupture lengths and total displacements for seven earthquakes in the USA for normal and strike slip fault type. However, they are general, and they don't cover necessary information for structural design. They are based on some specific earthquakes or for specific areas and information are just several evens.

2. METHODOLOGY

To understand the ground surface deformation due to earthquake, firstly important factors should be identified. Source fault is the most important factor, and has two main sub-factors such as geometry and fault displacement as shown in Figure 1a. For the geometrical parameters, length (L), width (W), dip angle (δ) of the source fault and distance from the top of source fault to ground surface (D_{TSF}) were considered. For the fault displacement, slip (S) and rake angle (λ) were considered. Fault type can be identified the rake angle (λ) as shown in Figure 1b. There are three main fault types, strike slip (S.S.) for λ around zero or ±180°, dip slip (D.S.) for λ around +90° for reverse slip (R.S.) and around -90° for normal slip (N.S.) and oblique slip (O.S.) where λ is between strike slip and dip slip.

The ground surface deformations are generally characterized as two types, discontinuous deformations or fault raptures and continuous deformations or deflection without marked rupture. The focus of this study is the continence deformation or deflection of the ground surface.

For vertical movements shown in Figure 2a, the vertical distance between two points on hanging wall and foot wall at the ground slope of θ= 1/500 was measured for total vertical deflection offset (V_T). For horizontal movements shown in Figure 2b, the horizontal distance along the strike of the fault between two points of shear strain of γ=1/500 was measured for total horizontal deflection offset (H_T).

The information of field data from past earthquakes were gathered from some famous data centers such as U.S. Geological Survey (U.S.G.S.), Southern California Earthquake Data Center (SCEDC) and also some geotechnical journals cited under references.

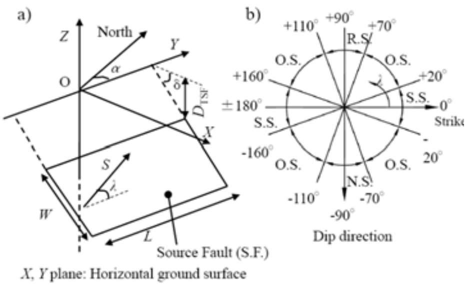

Figure 1: a) Source fault parameter, and b) fault type based on rake angle

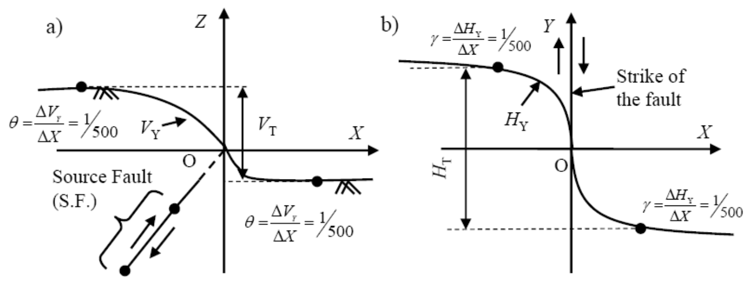

Figure 2: Definition of surface deflection: a) Cross section for vertical deflection, and b) Plane view for horizontal deflection

3. RESULTS AND DISCUSSIONS

In Figure 3, total horizontal deflection offset/ average slip (H_T/ S_{avg}) and total vertical deflection offset/ average slip (V_T/ S_{avg}) vs. rake angle (λ) are plotted. The ratio of H_T/ S_{avg} is maximum in strike slip and minimum in dip slip. The ratio of V_T/ S_{avg} is maximum in dip slip and minimum in strike slip. As shown in the figures, H_T/ S_{avg} at strike skip and V_T/ S_{avg} at dip slip are higher than unity. According to the dislocation theory, based on continuum mechanism the ground surface deflection should be less than slip on the source fault. However, in practice discontinuous mechanisms happened and as shown in the figures H_T in strike slip and V_T in dip slip are larger than S_{avg}.

The upper limit can be specified for H_T/ S_{avg} and V_T/ S_{avg}. The upper limits are considered same for strike slip and dip slip ranges, also for different ranges of strike slip (i.e. right-lateral and left-lateral) and different dip slips (i.e. reverse-slip and normal-slip), same value was considered. These rages are shown in Figure 1b. Also, the maximum value of H_T /S_{avg} and V_T /S_{max} for each earthquake selected and the average line for these maximum values were determined. Same rules as upper limit were used for plotting the average line. These upper limit and average lines can be used as guidelines in engineering design. The value of H_T/S_{avg} and V_T/S_{avg} can be selected between these lines based on the project criteria and requirement.

S_{avg} has two components, along the strike direction ($S_{avg}\cos\lambda$) and along the vertical component ($S_{avg}\sin\lambda\sin\delta$). The relationships between total horizontal deflection offset/ average slip along the strike direction ($H_T / S_{avg}\cos\lambda$), total vertical deflection offset/ vertical component of average slip ($V_T / S_{avg}\sin\lambda\sin\delta$) and rake angle ($\lambda$) are shown in Figure 4. Same as H_T/S_{avg} and V_T/S_{avg}, the upper limit and average lines for the $H_T/S_{avg}\cos\lambda$ and $V_T/S_{avg}\sin\lambda\sin\delta$ were drawn. For $H_T/S_{avg}\cos\lambda$, the maximum value is infinite and happened at pure dip slip (λ=±90°), because theoretically average slip along the strike direction is zero in pure dip slip. For $V_T/S_{avg}\sin\lambda\sin\delta$, the maximum value is infinity and happened at pure strike slip (λ=0°,±180°). The field data are relatively more fit with theory rather than the $H_T/S_{avg}\cos\lambda$, same pattern can be seen for $V_T/S_{avg}\sin\lambda\sin\delta$.

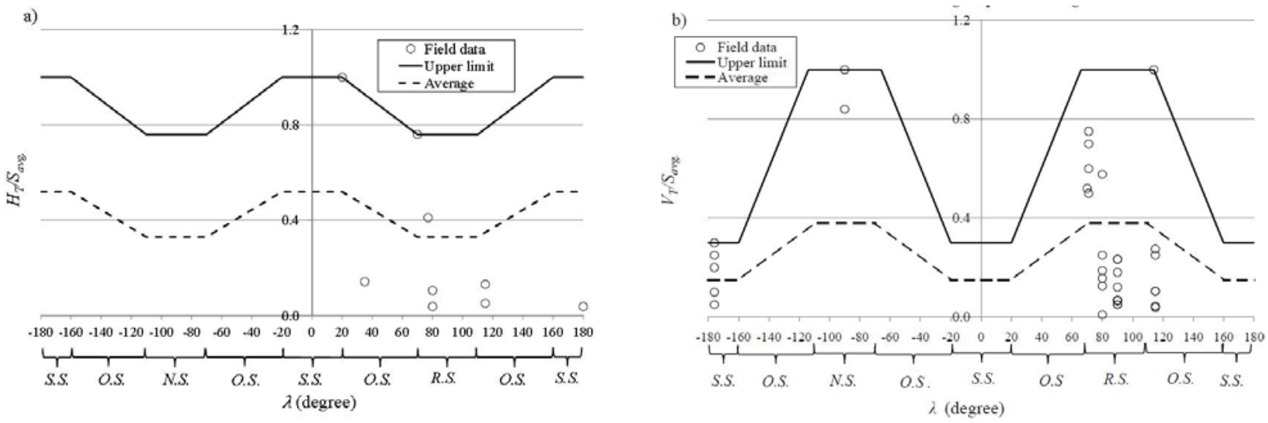

Figure 3: a) Total horizontal deflection offset/average slip vs. rake angle, and
b) Total vertical deflection offset/average slip vs. rake angle

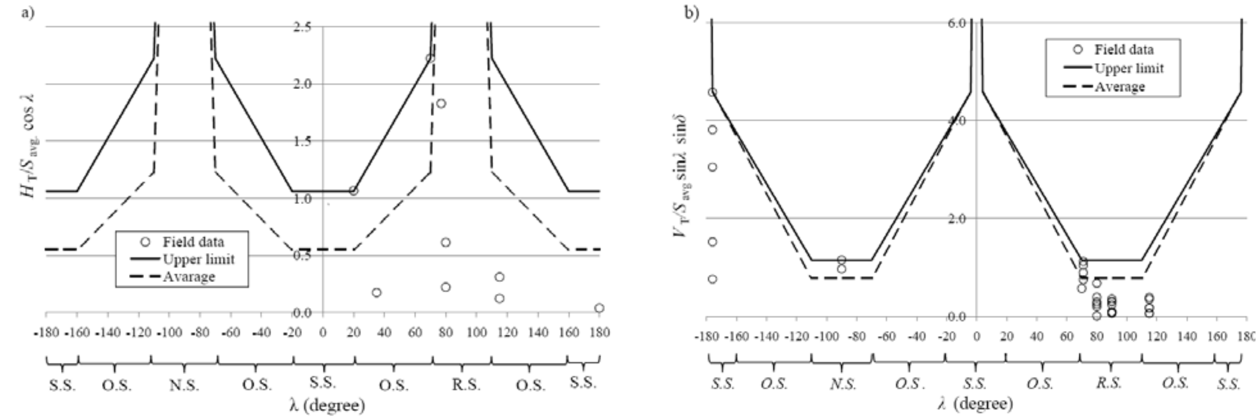

Figure 4: a) Total horizontal deflection offset/ average slip along the strike direction vs. rake angle, and
b) Total vertical deflection offset/vertical component of average slip vs. rake angle

4. CONCLUSIONS

Current empirical methods consider only some factors or only cover specified region. In this study, the most important factor in ground surface deflection was identified the type of fault and this can be specified by the rake angle. The next important factor is displacement of the source fault. According to the dislocation theory, based on continuum mechanism the ground surface deflection should be less than slip on the source fault. However , in practice discontinuous mechanisms happened and the horizontal deflection offset in strike slip and the vertical deflection offset in dip slip are larger than average slip on the source fault.

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