VERTICAL COMPONENT LEVEL OF SEISMIC GROUND MOTION VELOCITY

Olga Erteleva

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Schmidt Institute of Physics of the Earth, RAS, RUSSIA
ertel@ifz.ru

Abstract

Today it is considered proven that the vertical component of seismic ground motion makes a significant contribution to seismic loads on structures. For practical use in engineering calculations, it is necessary to assess the level of the vertical component. Taking into account growing interest to velocity of seismic oscillations, it is necessary to make such investigation and for vertical component of the seismic ground motion velocity. To solve this problem, the world empirical database of strong ground motions parameters of the earthquakes was used. Methods of statistical data processing were used. The first stage was the investigation of the ratio between the peak amplitudes of the maximal horizontal and vertical components of ground motion velocity, as well as the dependence of this ratio on the distance and magnitude of the seismic event It has been established that the dependence on magnitude is negligible. Taking into account the fact, that seismic oscillations in the near- and far- field zones of earthquakes have the different laws, further the dependence on distance was studied separately in each zone. As a result, correlation relationships for assessing the level of the vertical component of the velocity of expected seismic ground vibrations were developed, and the corresponding correlation coefficients and standard deviation values were computed. The obtained results can be used in calculating seismic treatments for the purposes of design and construction of seismic resistant structures.

Keywords: velocity, vertical component, amplitude, ratio, distance, seismic treatments

I. Introduction

One of the main tasks of providing comprehensive protection against earthquakes, which must be solved to reduce seismic risk, to decrease economic damage and human losses during earthquakes, is the seismic hazard assessment and the forecast of expected seismic treatments. In modern seismic resistant construction, seismic treatments are described by various quantitative parameters. The most commonly used one is acceleration; its characteristics have been studied in numerous works [1 – 7, etc.].

However, today in the practice of engineering calculations it is often necessary to take into account the velocity of seismic ground motions [8 – 11]. Nevertheless, this parameter has not yet been studied enough. In the scientific literature, one can mainly find only velocity attenuation equations [12 – 15, etc.]. Some authors propose the attenuation equations for vertical component of velocity [14, 16, 17, etc.]. The other characteristics are not practically researched. The vertical component of velocity also remains uninvestigated, although the need for such investigation is beyond doubt.

If special field observations are not carried out and the acceleration is used as the characteristics of seismic treatments, the level of the vertical component of acceleration is determined through the peak amplitude of the maximal horizontal component of ground motion. It was established that the relation between the accelerations on vertical and horizontal components significantly depend only on level of vibration [18].

Similar investigations for velocity of seismic ground motion have not been carried out.

The issue of the ratio of amplitudes on different components is very important, first of all, from a practical point of view. After all, if, as in the case of accelerations, there is a certain relationship between the levels of velocities on different components, then there is also the possibility of limiting research to studying only the maximal horizontal component of velocity of seismic ground motion.

II. Methods

To investigate the problem of assessing the level of vertical component of seismic ground motion velocity, the world empirical database of strong ground motions parameters of the earthquakes from different regions of the world with different tectonic settings was used. The interval of earthquake magnitude is $2 \le M_S \le 8$. The used distance was the shortest distance to the rupture surface. The interval of such distance is 0.01 km $\le R \le$ 100 km. The soils were classified into 4 groups by seismic properties according to Russian building codes.

Used research method is statistical analysis of empirical data on strong ground motions.

The study contained several stages:

- firstly, the ratio between the vibration amplitude of the vertical component and the amplitude of the maximal horizontal component was considered;
- secondly, the influence of earthquake magnitude and distance on this ratio was considered;
- thirdly, mentioned above ratio was considered in both near- and far-field zone separately.

Finally, for each developed correlated relations the standard deviation and correlation coefficient were defined.

III. Results

So, let us consider the ratio of the oscillation amplitude of the vertical component PGV_{vert} and the maximal horizontal (or, what is the same, main) component PGV_{Hmax}. The ratio of the peak amplitudes of these components is presented in Figure 1.

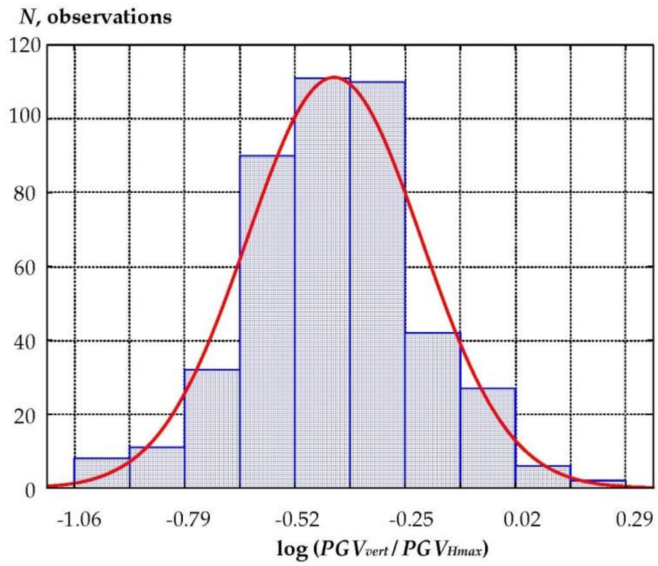

Figure 1: *Ratio of peak amplitudes of the vertical and maximal horizontal components (439 events). Red line is Gaussian distribution with parameters -0.43 ± 0.21.*

The average value of this ratio for a sample of 439 events is -0.43 units decimal logarithm, standard deviation σ = 0.21. The peak amplitude value of the vertical component is approximately 60% less than the peak value of the more intense horizontal component.

The dependence of the oscillation amplitude of the vertical component on the maximal horizontal one is graphically presented in Figure 2.

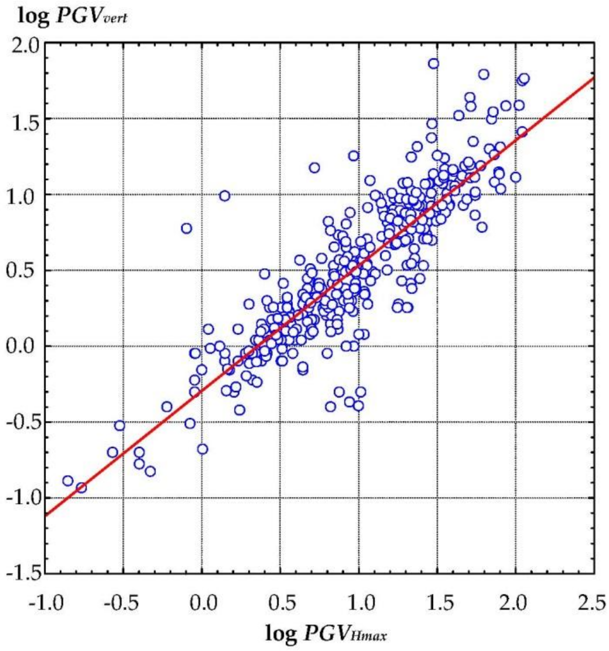

Figure 2: *Dependence of PGV_{vert} on PGV_{Hmax}.*
Circles are the empirical data (439 events); red line is approximating straight line

This relation is described by the equation:

$$\log PGV_{vert} = 0.82 \log PGV_{Hmax} - 0.29 \pm 0.29 \quad (1)$$

where PGV_{vert} - peak ground velocity (a maximal oscillation amplitude) of the vertical component, PGV_{Hmax} - peak ground velocity (a maximal oscillation amplitude) of maximal horizontal component (or, what is the same, main component).

The correlation coefficient in this case is $r = 0.87$.

With distance, the difference in levels between the vertical and maximal horizontal components increases, i.e. the vertical one grows faster, and with increasing magnitude, on the contrary, it decreases (Figure 3).

The corresponding formula for a sample of 159 events is:

$$\log (PGV_{vert} / PGV_{Hmax}) = 0.19 \log R - 0.06\, M_S - 0.38 \pm 0.33. \quad (2)$$

However, as can be seen from formula (2), the ratio of the levels of the vertical and maximal horizontal components to the magnitude is insignificant. The dependence on distance requires additional study.

Let us consider the dependence of the ratio of the amplitudes of the vertical and maximal horizontal components on distance separately for the near - and far – field zones. The relationship between far-field amplitudes ratio and distance is shown in Figure 4.

The equation of the approximating line has the form:

$$\log (PGV_{vert} / PGV_{Hmax}) = 0.08 \log R - 0.57 \pm 0.28. \quad (3)$$

As it is seen from equation (3,) the change in the value of log (PGV_{vert} / PGV_{Hmax}) over the entire considered range of distances does not exceed the standard deviation. So, the dependence on distance can also be neglected.

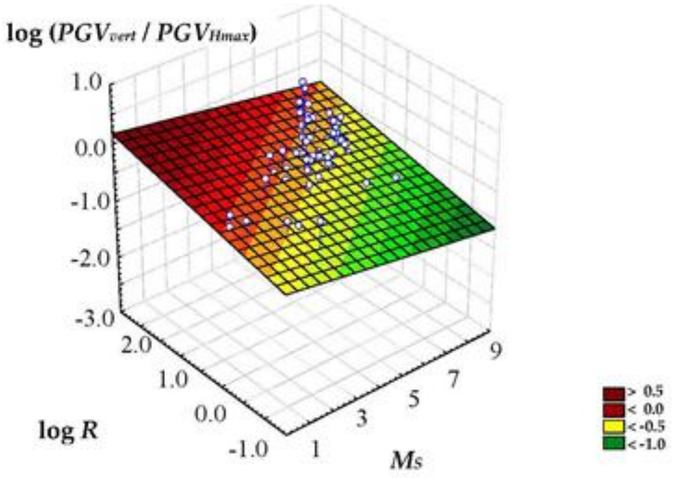

Figure 3: *Dependence of the ratio log (PGV_{vert} / PGV_{Hmax}) on the magnitude M_S and distance R. Circles are empirical data (159 events)*

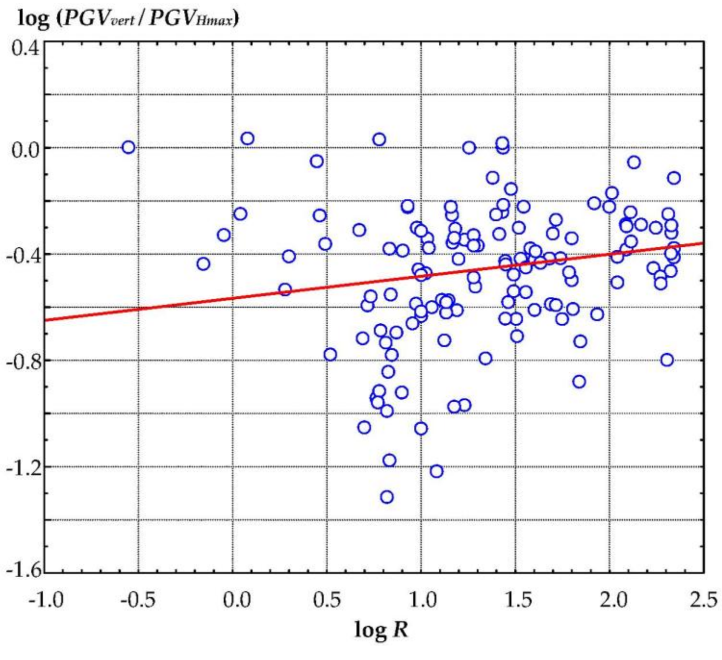

Figure 4: *Dependence of the value log (PGV_{vert} / PGV_{Hmax}) on the distance in the far-field zone. Circles are empirical data (144 events); red line is approximating straight line*

A similar picture is observed in the near - field zone.

Note, that magnitude and distance in equation (2) are correlated: small magnitudes are recorded only at short distances. As has been shown, the dependence of log (PGV_{vert} / PGV_{Hmax}) value on both distance and magnitude is insignificant. Therefore, equation (2) does not adequately describe the real dependencies. It is not for nothing that the distribution of the value log (PGV_{vert} / PGV_{Hmax}) without taking into account any factors (see Figure 1) has a lower standard deviation.

Let us consider the relationship between the levels of vertical and maximal horizontal components in the near - and far – field zones separately.

For the near -field zone (Figure 5)

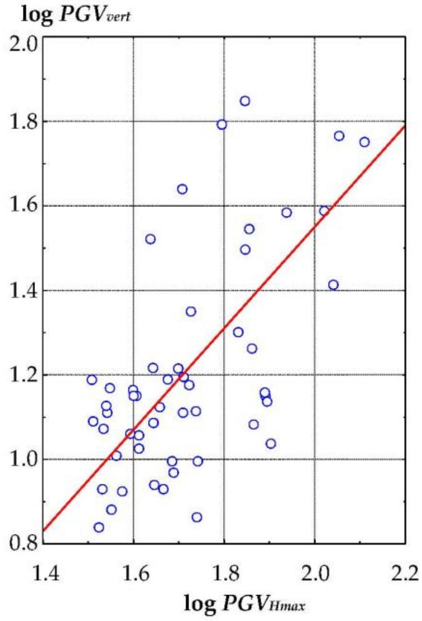

Figure 5: *Dependence of PGV_{vert} on PGV_{Hmax} in the near-field zone.*
Circles are empirical data (58 events); red line is approximating straight line

we have the next correlation relation:

$$\log PGV_{vert} = 1.20 \log PGV_{Hmax} - 0.85 \pm 0.14, \quad (4)$$

moreover, in the far-field zone (Figure 6)

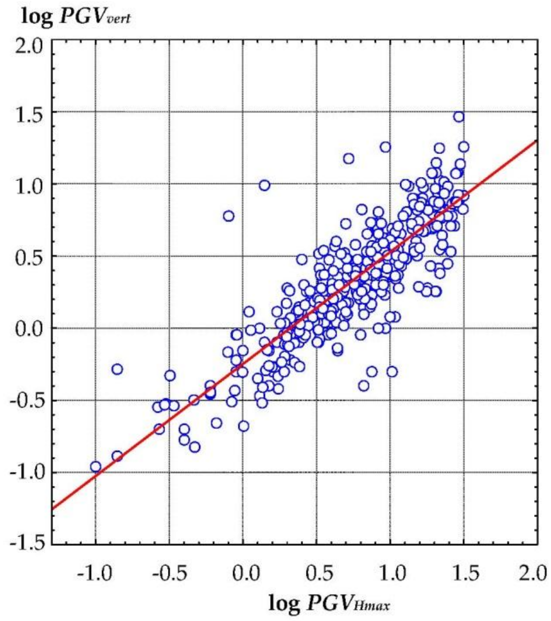

Figure 6: *Dependence of PGV_{vert} on PGV_{Hmax} in the far-field zone.*
Circles are empirical data (379 events); red line is approximating straight line

the relation was obtained

$$\log PGV_{vert} = 0.78 \log PGV_{Hmax} - 0.25 \pm 0.20. \quad (5)$$

The correlation coefficient of this relationship is high: $r = 0.87$.

IV. Discussion

Thus, as the empirical data analysis shows, the level of vertical component of seismic ground motion velocity is approximately in 1.7 times less than the peak value of the more intense horizontal component. It is the average estimation, without taking into account any factors as ground types at the observations point, the type of source mechanism, the distance and magnitude.

The influence of earthquake magnitude on the relation between the amplitudes of peak ground velocity of vertical component and the maximal horizontal component is insignificant. This relation is dimensionless value. In according the theory of dimension and similarity, the dimensionless quantity should not depend on the scale of the phenomenon.

As the result of research, the correlation relations for assessing the level of vertical velocity component were developed. These relations were obtained for near- and far-field zones of seismic wave field.

As in the case of accelerations, the relation between the velocities on vertical and horizontal components significantly depends on level of vibration. Therefore, the prediction of the amplitude level of the vertical velocity component of seismic ground motion is possible using data on the maximal horizontal component.

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