AN INTEGRATED ESTIMATE OF GROUND MOTION

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Synopsis

A research work has been undertaken to try and estimate the most damaging ground motion that will occur at a given site.

The final output of the computer program will be the available record that better suits the conditions of our particular problem.

Symbols, abbreviations and definitions

a_{max} = peak horizontal ground acceleration (g). If resultant is not available, maximum component.

D = distance to the fault (km). If not available, epicentral distance.

d_f = resultant relative displacement at fault-break (m).

d_{max} = peak horizontal ground displacement (cm).

I = Modified Mercalli intensity.

L = fault-break length (km).

M = magnitud (Pasadena if possible).

S.E. = standard error.

T = average period (s). Duration divided by number of cycles. Only obtained when $a_{max} \geq 0.032g$.

T_r = "resonance period". Period corresponding to the maximum of the acceleration spectrum (s).

t = duration (s). Time that includes all pulses $\geq 3\ \%\ g$.

v_{max} = maximum horizontal velocity (cm/s).

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The following ground types have been considered:

Type 1. Rock

Type 2. Hard soil or pleistocene

Type 3. Soil of medium consistence or alluvium

Type 4. Deep, very soft soil

Type 5. Hard rock

Type 6. Soft rock

Introduction

Perhaps the most pressing need for Earthquake Engineering today is an adequate estimate of the most damaging ground motion that will occur at a given site, during a certain period of time, and for an accepted probabilistic risk.

But in many countries there are no strong motion accelerographs, or they have been so recently installed that no important record is available.

A seismic diagram has been defined by only a few parameters: maximum ground acceleration, velocity and displacement, duration, "resonance period", etc.

A thorough research has been undertaken to try and obtain these parameters from the data usually available in most countries: Intensity, magnitude, distance to the fault, ground conditions, type of source mechanism, etc. Preliminary results have been published previously (1 & 2).

Computer programming.

A large amount of the records available, including most of the data from the U.S., Japan and New Zealand, and some from Papua-New Guinea, have been examined and processed.

At present 1098 earthquakes, each one with many records(115 for S. Fernando earthquake), have been stored in some 10.000 punched cards. Many more will be introduced soon. Alphanumeric characters have been used.

A master file has been created in a magnetic tape accesible from different Fortran computer programs. An IBM 370/135 has been used.

Frequency distributions

Some frequency distributions for every value of Intensity --

are included in table I.

We see that, the harder the ground type, the larger the acceleration for a given Intensity. The standard error is less when - we consider a given ground type than if we consider "all" ground types together. If we refer to a given station, the standard error is still less. That emphasizes the importance of local data.

The ground type or the local station have no significant influence neither in velocity nor in displacement. The standard error of both is very small.

The acceleration data corresponding only to volume II of the books published by the California Institute of Technology are refered to as Caltech in table I. We see that the average acceleration is much larger than the one corresponding to "all" data. That is because the Caltech has probably selected preferently accelerograms with large values of peak acceleration. As the velocity and dis-- placement values correspond mainly to Caltech data, they may be - larger than the average corresponding to each intensity.

Regressions

Some linear regressions and the corresponding standard errors are indicated below:

$\log_{10} L = -1.30 + 0.39\,M$ (1) S.E. = 0,55

$\log_{10} d_f = 0.59\,M - 4.08$ (2) S.E. = 0.44

For I = IV $\log_{10} a_{max} = -0.31 \log_{10} D - 1.55$ (3)
S.E. = 0.47

I = V $\log_{10} a_{max} = -0.34 \log_{10} D - 1.23$ (4)
S.E. = 0.50

I = VI $\log_{10} a_{max} = -0.30 \log_{10} D - 1.10$ (5)
S.E.=0.52

I = VII $\log_{10} a_{max} = -0.49 \log_{10} D - 0.20$ (6)
S.E. = 0.24

I = VIII $\log_{10} a_{max} = -0.27 \log_{10} D - 0.14$ (7)
S.E. = 0.16

$\log_{10} a_{max} = -2.21 - 0.26 \log_{10} D - 0.19 (\log_{10} D)^2 + 0.31\,M$ (8)
S.E. = 0.39

For S. Fernando earthquake:

$$\log_{10} a_{max} = 0.59 - 0.99 \log_{10} D - 0.03 (\log_{10} D)^2 \qquad (9)$$

S.E. = 0.22

For acceleration:

$$\log_{10} T_r = - 0.05 + 0.84 \log_{10} T \quad (10) \qquad \text{S.E.} = 0.12$$

For velocity:

$$\log_{10} T_r = - 0.14 + 1.28 \log_{10} T \quad (11) \qquad \text{S.E.} = 0.37$$

For acceleration:

For hard rock: $\log_{10} T = 1.06 + 0.23 \log_{10} D$ (12)
S.E. = 0.22

For rock in general: $\log_{10} T_r = - 0.96 + 0.17 \log_{10} D$ (13)
S.E. = 0.19

For soft rock: $\log_{10} T_r = - 0.84 + 0.10 \log_{10} D$ (14)
S.E. = 0.16

For ground type 2: $\log_{10} T_r = \log_{10} 0.27$ (15)
S.E. = 0.18

For ground type 3: $\log_{10} T_r = - 0.67 + 0.08 \log_{10} D$ (16)
S.E. = 0.19

For ground type 4: $\log_{10} T_r = - 0.73 + 0.22 \log_{10} D$ (17)
S.E. = 0.22

$$\log_{10} t = 0.24 \log_{10} (a_{max} - 0.03) + 0.29 M - 0.7 \qquad (18)$$

S.E. = 0.45

Comments

If we compare the standard errors in table I and in the regressions indicated above, the following comments may be made:

For low values of intensity (up to I = VI) the peak acceleration is best estimated from magnitude and distance to the fault. On the other hand, for high values of intensity (I = VII & VIII) the peak acceleration is best estimated from intensity, specially if distance to the fault and ground type are included in the regressions.

Equation (10) shows that there is a good correlation between the "resonance period" and the average period, specially for accelerations. For this reason, in equations (12) to (17), whenever the resonance period was not available we have employed the average period instead.

The peak acceleration was not significant in the regression of resonance period.

In table II we show the influence of damping in resonance period for Caltech data. At least for horizontal acceleration the influence is very small.

For this reason we have averaged the resonance period for different dampings in equations (10) to (17).

Recently, Trifunac and Brady (3) have given a different definition of duration. The writers acknowledge that their definition is much more logical. A proof of that is the smaller error obtained from their estimate. The writers are adopting now Trifunac and Brady's definition in their master file.

Further improvements

Once the master file is ready, it is very easy to try more complicated regressions. E.g., the next try will be to introduce the type of ground in equations (3) to (7).

Once the parameters of the ground motion have been estimated, the last step will be to search in the master file and find out the available records that better suit the estimate.

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Table I

Frequency distributions of log a_{max}, log v_{max} and log d_{max}

I	Ground type or station	a_{max}		v_{max}		d_{max}	
		average	S.E.	average	S.E.	average	S.E.
IV	all	$\log_{10}$ 0.008	0.51	$\log_{10}$ 2.9	0.153		
	2 & 3	$\log_{10}$ 0.007	0.42				
	El Centro	$\log_{10}$ 0.010	0.34				
	S. Fco. S.P.	$\log_{10}$ 0.004	0.36				
	Ferndale	$\log_{10}$ 0.011	0.49				
	Hollister	$\log_{10}$ 0.009	0.45				
V	All	$\log_{10}$ 0.014	0.52	$\log_{10}$ 3.6	0.187	$\log_{10}$ 1.6	0.18
	Caltech	$\log_{10}$ 0.056	0.31				
	5	$\log_{10}$ 0.025	0.33				
	6	$\log_{10}$ 0.021	0.46				
	2	$\log_{10}$ 0.019	0.45				
	3	$\log_{10}$ 0.010	0.51				
	4	$\log_{10}$ 0.010	0.34				
	El Centro	$\log_{10}$ 0.015	0.34				
	S.Fco. S.P.	$\log_{10}$ 0.007	0.49				
	Ferndale	$\log_{10}$ 0.026	0.35				
	Hollister	$\log_{10}$ 0.014	0.35				
VI	all	$\log_{10}$ 0.024	0.56	$\log_{10}$ 7.6	0.293	$\log_{10}$ 3.2	0.31
	Caltech	$\log_{10}$ 0.074	0.35				
	1	$\log_{10}$ 0.076	0.52				
	2	$\log_{10}$ 0.033	0.55				
	3	$\log_{10}$ 0.018	0.51				
	El Centro	$\log_{10}$ 0.046	0.37				
	S. Fco. S.P.	$\log_{10}$ 0.014	0.20				
	Ferndale	$\log_{10}$ 0.059	0.29				
	Hollister	$\log_{10}$ 0.028	0.25				
VII	all	$\log_{10}$ 0.132	0.28	$\log_{10}$ 18.4	0.170	$\log_{10}$ 9.8	0.20
	Caltech	$\log_{10}$ 0.147	0.22				
	1	$\log_{10}$ 0.191	0.15				
	2	$\log_{10}$ 0.147	0.48				
	3	$\log_{10}$ 0.133	0.23				
VIII	all	$\log_{10}$ 0.322	0.22	$\log_{10}$ 23.4	0.079		

Table II

Influencia of critical damping in resonance period (Caltech data)

Damping %	Horizontal acceleration.		Vertical acceleration.		Horizontal velocity	
	Average	S.E.	Average	S.E.	Average	S.E.
0	0.29	0.21	0.22	0.18	1.60	1.53
2	0.33	0.26	0.29	0.38	2.56	2.27
5	0.35	0.29	0.32	0.44	3.01	2.54
10	0.33	0.26	0.30	0.43	3.33	2.74
20	0.29	0.19	0.26	0.30	4.38	3.48