

Comprehensive Methodology for Assessing Structural Response to Probable Seismic Motions: Application to Guatemala City

Carlos Gamboa-Canté^{1,3}, María Belén Benito², Omar Flores³ and Carlos Pérez-Arias³

¹*Escuela Técnica Superior de Ingenieros en Topografía, Geodesia y Cartografía, Universidad Politécnica de
Madrid, Madrid, 28031, Spain*

²*Departamento de Ingeniería y Morfología del Terreno, Escuela Técnica Superior de Ingenieros de Caminos,
Canales y Puertos, Universidad Politécnica de Madrid, 28040 Madrid, Spain*

³*Centro de Estudios Superiores de Energía y Minas, Facultad de Ingeniería, Universidad de San Carlos de
Guatemala, 01012 Guatemala City, Guatemala*

Supplementary Material

Supplement A

Geological description of the study area: USAC *campus*, Guatemala City, Guatemala.

Supplement B

Complementarity of the MASW and HVSR methods.

Supplement A

The study area is located within the *campus* of the Universidad de San Carlos de Guatemala (USAC), situated in the southern sector of Guatemala City. Geologically, the *campus* is underlain by volcanoclastic deposits of Quaternary age, which are widely distributed throughout the Guatemala City Valley (Fig. S1). These deposits correspond to sequences of pyroclastic materials, primarily air-fall and reworked volcanic ashes, pumice fragments, and tuffs, derived from explosive eruptions of nearby volcanic centers of the Central American Volcanic Arc.



Figure S1. Stratigraphic profile located on the western part of the USAC campus.

The stratigraphic profile exposed in excavations across the campus reveals massive to stratified layers of light-colored pyroclastic material, including pumiceous sands, silty volcanic ash, and locally interbedded gravel-rich horizons. The materials are generally poorly consolidated to weakly cemented, showing a friable texture and limited cohesion. Locally, thin horizons with darker, coarser material indicate episodes of higher-energy deposition or secondary reworking.

From a geotechnical perspective, these deposits are typically classified as silty sands (SM) and poorly graded sands with silt (SP-SM) according to the Unified Soil Classification System (USCS), although intercalations of pumice gravel may also be identified as GM/GP units. The materials exhibit moderate stiffness when dry, but are prone to loss of strength and collapse upon wetting or saturation, a behavior characteristic of pyroclastic soils in the region.

Supplement B

Below is Table S1 with the results obtained from the ambient vibration analysis of the soil using the HVSR method. The table shows the station name, geographic coordinates, UTM coordinates, soil resonance frequency, soil vibration period, the theoretical shear wave velocity value at 30 meters depth (Vs30), and the soil classification according to the national standard AGIES 2024 NSE 2.1.

Table S1. Seismic microzonation results using HVSR method.

Station	Geographic coordinates		UTM coordinates		Frequency (Hz)	Period (s)	Vs30 (m/s)	Soil Class AGIES 2024 NSE 2.1
	Longitude	Latitude	X	Y				
P1	-90.5662	14.5859	762221	1613924	0.44	2.27	---	---
P2	-90.5533	14.5892	763604	1614306	0.51	1.96	---	---
P3	-90.5524	14.5891	763698	1614302	0.55	1.82	---	---
P4	-90.5515	14.589	763800	1614286	0.44	2.27	235	D
P5	-90.5505	14.5891	763910	1614300	0.38	2.63	---	---
P6	-90.5497	14.5892	763991	1614310	0.25	4.00	---	---
P7	-90.5485	14.589	764124	1614292	0.28	3.57	---	---
P8	-90.5543	14.5883	763500	1614203	1.02	0.98	235	D
P9	-90.5535	14.5882	763585	1614199	0.44	2.27	---	---
P10	-90.5524	14.5882	763707	1614194	0.25	4.00	---	---
P11	-90.5512	14.5883	763837	1614207	0.28	3.57	---	---
P12	-90.5501	14.5879	763953	1614168	0.47	2.13	443	C
P13	-90.5497	14.5877	763991	1614142	0.41	2.44	331	CD
P14	-90.5487	14.5885	764106	1614233	0.50	2.00	---	---
P15	-90.5479	14.5883	764192	1614218	0.47	2.13	334	CD
P16	-90.5468	14.5883	764302	1614221	0.50	2.00	---	---
P17	-90.5459	14.5883	764403	1614217	0.69	1.45	---	---
P18	-90.5543	14.5873	763495	1614101	1.00	1.00	380	CD
P19	-90.5533	14.5873	763608	1614099	0.28	3.57	---	---
P20	-90.5525	14.5871	763694	1614075	0.34	2.94	---	---
P21	-90.5514	14.5874	763811	1614114	0.44	2.27	---	---
P22	-90.5506	14.5875	763901	1614120	0.53	1.89	---	---
P23	-90.5495	14.5871	764019	1614077	0.44	2.27	336	CD
P24	-90.5485	14.5875	764121	1614130	0.47	2.13	339	CD
P25	-90.5477	14.5874	764208	1614121	0.47	2.13	---	---
P26	-90.5469	14.5873	764297	1614102	0.44	2.27	---	---
P27	-90.546	14.5873	764390	1614105	0.47	2.13	210	D
P28	-90.5544	14.5865	763494	1614003	0.22	4.55	---	---
P29	-90.5533	14.5865	763605	1614010	0.31	3.23	429	CD
P30	-90.5524	14.5865	763700	1614007	0.44	2.27	---	---
P31	-90.5514	14.5866	763808	1614026	0.44	2.27	418	CD
P32	-90.5506	14.5864	763903	1614006	0.44	2.27	---	---
P33	-90.5498	14.5864	763990	1614002	0.60	1.67	---	---
P34	-90.5488	14.5865	764091	1614018	0.28	3.57	---	---
P35	-90.5472	14.5868	764261	1614045	0.45	2.22	---	---
P36	-90.5471	14.5864	764277	1614010	0.28	3.57	---	---
P37	-90.5459	14.5867	764401	1614040	0.63	1.59	---	---
P38	-90.556	14.5855	763322	1613901	0.63	1.59	---	---
P39	-90.555	14.5858	763429	1613928	0.56	1.79	461	C
P40	-90.5544	14.5856	763495	1613910	0.41	2.44	402	CD
P41	-90.5533	14.5855	763604	1613903	0.63	1.59	380	CD

P42	-90.5526	14.5855	763687	1613905	0.63	1.59	340	CD
P43	-90.5516	14.5855	763797	1613905	0.63	1.59	511	C
P44	-90.5507	14.5856	763894	1613911	0.55	1.82	---	---
P45	-90.5498	14.5855	763983	1613904	0.43	2.33	---	---
P46	-90.5478	14.5856	764198	1613918	0.41	2.44	227	D
P47	-90.5471	14.5853	764280	1613887	0.47	2.13	217	D
P48	-90.546	14.5854	764399	1613896	0.31	3.23	---	---
P49	-90.5582	14.5847	763084	1613803	1.01	0.99	455	C
P50	-90.5572	14.5846	763187	1613798	0.63	1.59	---	---
P51	-90.5562	14.5847	763300	1613808	0.60	1.67	---	---
P52	-90.5552	14.5845	763402	1613785	0.60	1.67	---	---
P53	-90.5543	14.5846	763506	1613799	0.47	2.13	---	---
P54	-90.5534	14.5847	763602	1613806	0.52	1.92	---	---
P55	-90.5526	14.5848	763688	1613820	0.38	2.63	---	---
P56	-90.5516	14.5846	763798	1613800	0.22	4.55	475	C
P57	-90.5592	14.5836	762973	1613685	0.25	4.00	---	---
P58	-90.5581	14.5837	763095	1613699	0.30	3.33	---	---
P59	-90.5574	14.5841	763172	1613739	0.44	2.27	---	---
P60	-90.556	14.5843	763321	1613765	0.50	2.00	280	D
P61	-90.5552	14.5838	763409	1613707	0.48	2.08	---	---
P62	-90.5542	14.5838	763510	1613712	0.59	1.69	---	---
P63	-90.5536	14.5837	763584	1613696	0.25	4.00	---	---
P64	-90.5522	14.5839	763727	1613724	0.41	2.44	250	D
P65	-90.559	14.5828	762994	1613592	0.60	1.67	---	---
P66	-90.558	14.5828	763108	1613598	0.61	1.64	---	---
P67	-90.5571	14.5826	763201	1613579	0.44	2.27	441	C
P68	-90.5564	14.5831	763283	1613628	0.45	2.22	---	---
P69	-90.5554	14.5832	763388	1613639	0.44	2.27	---	---
P70	-90.5543	14.5829	763501	1613615	0.43	2.33	---	---
P71	-90.5537	14.583	763571	1613620	0.44	2.27	290	D
P72	-90.559	14.5819	763003	1613496	0.28	3.57	---	---
P73	-90.558	14.5818	763102	1613490	0.38	2.63	449	C
P74	-90.5572	14.582	763191	1613502	0.59	1.69	300	CD
P75	-90.5561	14.5819	763311	1613502	0.25	4.00	---	---
P76	-90.5553	14.5819	763399	1613499	0.44	2.27	320	CD
P77	-90.5544	14.582	763498	1613506	0.41	2.44	350	CD
P78	-90.5534	14.5821	763599	1613519	0.22	4.55	---	---
P79	-90.559	14.5811	763000	1613408	0.22	4.55	---	---
P80	-90.558	14.5811	763105	1613406	0.23	4.35	---	---
P81	-90.5572	14.581	763196	1613392	0.53	1.89	---	---
P82	-90.5562	14.581	763303	1613395	0.31	3.23	---	---
P83	-90.5553	14.581	763393	1613394	0.41	2.44	472	C
P84	-90.5543	14.581	763502	1613400	0.47	2.13	---	---
P85	-90.559	14.5802	763000	1613309	1.53	0.65	430	CD
P86	-90.5581	14.5802	763097	1613302	0.41	2.44	370	CD
P87	-90.5572	14.58	763198	1613282	0.40	2.50	---	---
P88	-90.5562	14.5801	763301	1613297	0.45	2.22	---	---
P89	-90.5553	14.5801	763401	1613298	0.38	2.63	---	---
P90	-90.5544	14.5801	763500	1613303	0.41	2.44	407	CD
P91	-90.5591	14.5792	762994	1613196	0.25	4.00	---	---
P92	-90.5581	14.5793	763099	1613204	0.38	2.63	---	---
P93	-90.5572	14.5791	763192	1613189	0.59	1.69	492	C
P94	-90.5562	14.5792	763302	1613196	0.31	3.23	---	---
P95	-90.5552	14.5791	763412	1613189	0.50	2.00	420	CD
P96	-90.5592	14.5784	762986	1613105	0.25	4.00	---	---

P97	-90.5581	14.5783	763097	1613096	0.62	1.61	341	CD
P98	-90.5572	14.5784	763202	1613105	0.51	1.96	---	---
P99	-90.5563	14.5783	763298	1613099	0.59	1.69	471	C
P100	-90.558	14.5775	763112	1613009	0.47	2.13	389	CD
P101	-90.5572	14.5774	763196	1612997	0.31	3.23	---	---
P102	-90.5562	14.5774	763303	1613001	0.53	1.89	---	---
P103	-90.5555	14.5775	763381	1613006	0.63	1.59	440	CD

Table S2 presents the results obtained with the MASW method. The table shows the station name, geographic coordinates, UTM coordinates, the theoretical shear wave velocity value at 30 meters depth (Vs30), and the soil classification according to the national standard AGIES 2024 NSE 2.1.

Table S2. Seismic microzonation results using MASW method.

<i>Estación</i>	<i>Geographic coordinates</i>		<i>UTM coordinates</i>		<i>Vs30 (m/s)</i>	<i>Soil Class AGIES 2024 NSE 2.1</i>
	<i>Longitude</i>	<i>Latitude</i>	<i>X</i>	<i>Y</i>		
M1	-90.5535	14.589	763583	1614286	310	CD
M2	-90.5542	14.5879	763510	1614160	440	CD
M3	-90.5536	14.5863	763574	1613983	429	CD