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Seismic Vulnerability Analysis Using Qualitative and Quantitative Methods and Structural Strengthening Proposal for Self-Built Dwellings in Latin American Informal Settlements

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Abstract -The present study aims to categorize the seismic vulnerability levels of self-built dwellings located in the informal settlement of Puyusca, in the district of Villa María del Triunfo, Lima, Peru. To achieve this, two qualitative evaluation methods were applied: the Benedetti-Petrini methodology and the FEMA P-154 rapid visual screening procedure. The Benedetti-Petrini approach assesses eleven weighted structural and geometric parameters, assigning vulnerability grades ranging from A to D. The cumulative score yields both a Vulnerability Index (Iv) and a standardized vulnerability index (Ivn), which enable the comparative classification of building stock. In parallel, the FEMA P-154 method utilizes a standardized data collection form that incorporates key seismic risk factors such as soil conditions, structural irregularities, and construction typology. This method computes a preliminary seismic score which, when contrasted with a defined threshold, determines the building's vulnerability level.
A statistically representative sample of 120 dwellings was evaluated. Prior to the field campaign, the research team conducted informational sessions with local community leaders and stakeholders to secure consent for data collection. Field assessments were carried out in coordination with municipal authorities. Structural layouts and seismic vulnerability mapping were performed using AutoCAD. Subsequently, three typologically representative dwellings were selected for detailed numerical modeling in ETABS. The models incorporated the actual geometry, material properties, and load conditions to simulate seismic behavior. Interstory drift ratios were analyzed as primary indicators of seismic demand. A structural strengthening strategy involving welded wire mesh (WWM) retrofitting was proposed and numerically validated. The results indicated a significant increase in shear capacity (Vm) of the retrofitted masonry walls, with improvements ranging from 19% to 30%. Furthermore, the inelastic drift demands were substantially reduced, particularly at roof level of the first stories, with decreases of 8.30%, 13.51%, and 17.42%, respectively. These outcomes demonstrate the effectiveness of WWM retrofitting in enhancing seismic performance in informal self-built housing.

***Keywords*: Welded wire mesh, structural strengthening, seismic vulnerability, confined masonry, FEMA P154, Benedetti-Petrini**

1. Introduction

Peru is located along the Pacific Ring of Fire, where the South American Plate and the Nazca Plate converge, forming an active subduction zone with constant tectonic activity. In this region, no less than 80% of the accumulated energy is released annually in the form of earthquakes [1].

One of the most pressing and persistent structural deficiencies in Peru is the widespread practice of unregulated self-construction, often carried out without technical oversight or quality control. Homeowners typically seek to reduce construction costs by foregoing professional engineering services. As reported by Arboccó [2], most families contract a foreman who executes the entire range of construction activities—including masonry, rebar placement, formwork, and concrete pouring—while also undertaking tasks traditionally assigned to licensed professionals, such as design and construction supervision. In many cases, this individual assumes full responsibility for developing architectural drawings and directing the works on-site, despite lacking formal training in architecture, structural engineering, or the design of electrical and sanitary systems. Consequently, these dwellings exhibit critical structural vulnerabilities. For instance, in the district of Villa María del Triunfo, homes often feature low wall density due to the homeowners' preference for open-plan layouts. It is common for the entire footprint of the plot to be roofed over, frequently without incorporating required light and ventilation shafts, in direct violation of the Peruvian National Building Code (RNE).

This pattern of informal construction, driven by financial limitations and the desire to reduce expenses, results in poorly conceived structural systems and frequent design errors. Moreover, the lack of public awareness concerning proper construction practices further exacerbates the problem, significantly undermining the habitability and safety of these structures [3].

Villa María del Triunfo is located along Peru's coastal seismic corridor and, according to the Peruvian Seismic Design Code E.030, lies within Seismic Zone 4, classified as a high-hazard area due to its geotectonic setting within the Pacific Ring of Fire. Under such conditions, any housing unit constructed without professional engineering input becomes inherently vulnerable to seismic loading.

Perez and Romero [4] underscore the importance of assessing the housing stock in the informal settlement of Puyusca, located in the same district, not only because of its exposure to high seismicity but also due to the informal and technically unsupported nature of its construction. Additionally, geotechnical studies indicate that these dwellings are founded on silty sand and poorly graded sandy soils extending to depths of approximately 3 meters—conditions that further compromise structural performance under seismic excitation.

2. Methods and Study Area

This research assesses the seismic vulnerability of dwellings located in the informal settlement of Puyusca through a comprehensive methodological framework that integrates both qualitative and quantitative techniques. The evaluation process is structured in three phases: initially, rapid visual screening (RVS) is performed using the FEMA P-154 protocol and the Benedetti-Petrini method, allowing for a preliminary estimation of seismic vulnerability levels. Subsequently, a numerical analysis of interstory drifts is conducted through structural modeling using ETABS software, with the objective of quantifying the dynamic response of the evaluated buildings. The combination of these methods enables a more accurate characterization of the vulnerability level across the assessed housing units.

2.1. Qualitative and Quantitative Methods

Rapid Visual Screening (RVS) methods are diagnostic tools that facilitate the preliminary evaluation of seismic vulnerability in buildings through visual inspection [5]. In this study, the FEMA P-154 and INDECI methods were employed.

- **FEMA P-154**: This methodology enables rapid classification of buildings based on observable structural and geometric characteristics. Information such as total floor area, year of construction, design year, number of stories, building configuration, structural materials, and irregularities are collected as part of the vulnerability assessment process [6, 7, 8, 12].
- **Benedetti-Petrini Method**: This method evaluates 11 parameters, each categorized from A to D, with assigned weights. The combination of scores provides a Vulnerability Index (Iv), which has been widely used and validated through applications in countries such as Spain, Italy, Colombia, Ecuador, and Peru, among others [9, 10].

The quantitative method, based on interstory drift analysis, complements the qualitative evaluation by employing ETABS for detailed structural modeling and dynamic simulation of the buildings under gravitational and seismic loading. The models incorporate the actual geometry and mechanical properties of materials. One of the key indicators used is the interstory drift ratio, which serves as a proxy for structural deformation demand under seismic excitation. Elevated drift ratios correlate with increased probability of both structural and non-structural damage, thereby offering a means to quantify the seismic performance of the buildings.

2.2. Study Area Description

The present study was conducted in the informal settlement of Puyusca, located in the district of Villa María del Triunfo, Lima Metropolitan Area, Peru (see Figure 1). The total housing stock comprises 190 units, and a statistically representative sample of 120 dwellings was selected for analysis.

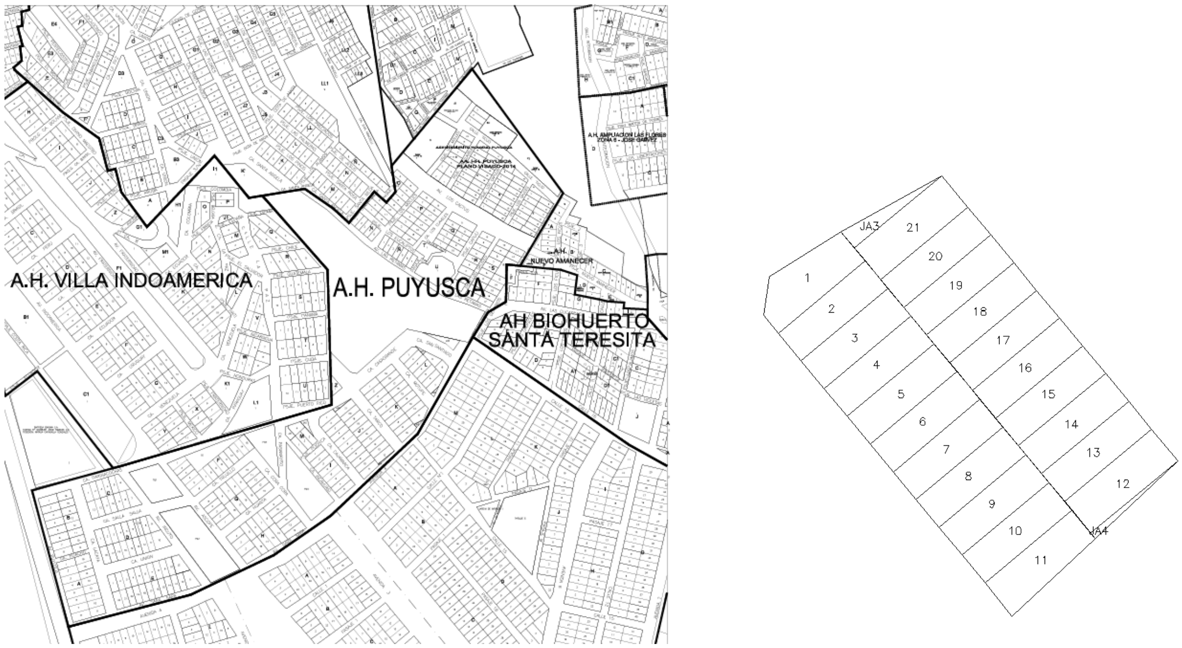

Fig. 1: Plot Subdivision and Block 'J' Diagram of the Puyusca Informal Housing Sector

According to the Peruvian Seismic Design Code (E.030) [11], the national territory is divided into four seismic zones, and every structure must be designed in accordance with the parameters corresponding to its respective zone. As shown in Figure 2.a, the Puyusca settlement is situated in Seismic Zone 4. Geotechnical investigations conducted in nearby areas provided soil characterization data relevant to this study. A total of 18 trial pits were excavated, revealing a composition of approximately 80% sand, 10% silt, and 10% gravel. Based on the Unified Soil Classification System (USCS), the soil was classified as SM (silty sand). Furthermore, the soil profile was identified as S3 (Figure 2.b), which corresponds to a soft soil condition according to E.030.

Zona	Z
4	0.45
3	0.35
2	0.25
1	0.1

Perfil	$\bar{V}_s$	$\bar{N}_{60}$	$\bar{S}_u$
S_0	> 1500 m/s	-	-
S_1	500 m/s a 1500 m/s	> 50	>100 kPa
S_2	180 m/s a 500 m/s	15 a 50	50 kPa a 100 kPa
S_3	< 180 m/s	< 15	25 kPa a 50 kPa
S_4	Clasificación basada en el EMS		

Fig. 2.a. Seismic Zoning in Peru / Fig. 2.b. Soil profiles

3. Results

Figure 3 shows a sample of the dwellings surveyed during the fieldwork, while Figure 4 presents the floor plans of three representative housing units selected for quantitative evaluation based on interstory drift ratios.

Fig. 3. Images of Residential Structures in the Puyusca Informal Settlement

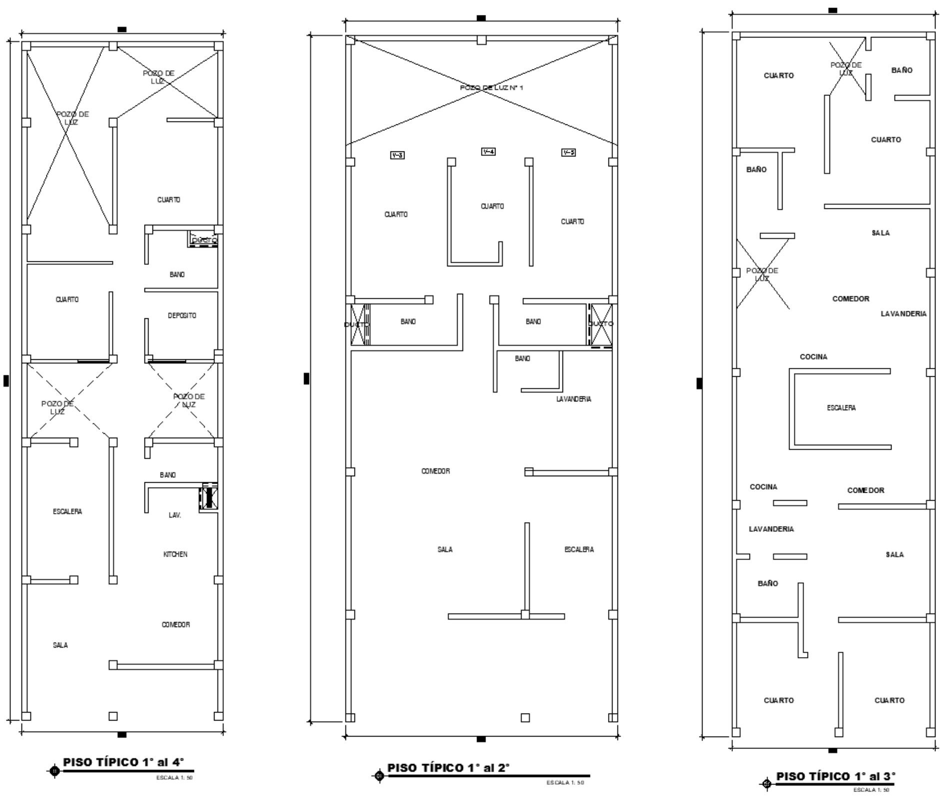

Fig. 4. Floor Plans of the Representative Dwellings in the Puyusca

Figure 5 shows the seismic vulnerability levels of the dwellings according to the Benedetti-Petrini method. It is evident that more than 80% of the houses exhibit high vulnerability levels. On the right side of the figure, the FEMA P-154 results are presented, which indicate that 100% of the dwellings evaluated fall within the vulnerable category.

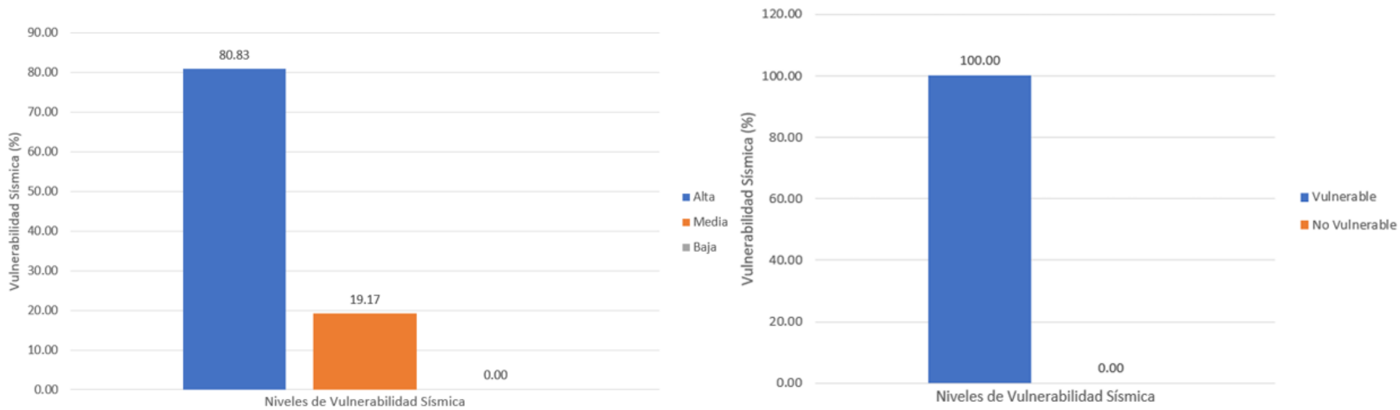

Fig. 5. Seismic Vulnerability Results of Dwellings According to Benedetti-Petrini (left) and FEMA P-154 (right)

Figure 6 provides the seismic vulnerability maps generated from both rapid screening methods. These maps underscore the critical need for structural intervention, as a considerable portion of the housing stock may suffer significant damage in the event of a high-magnitude earthquake.

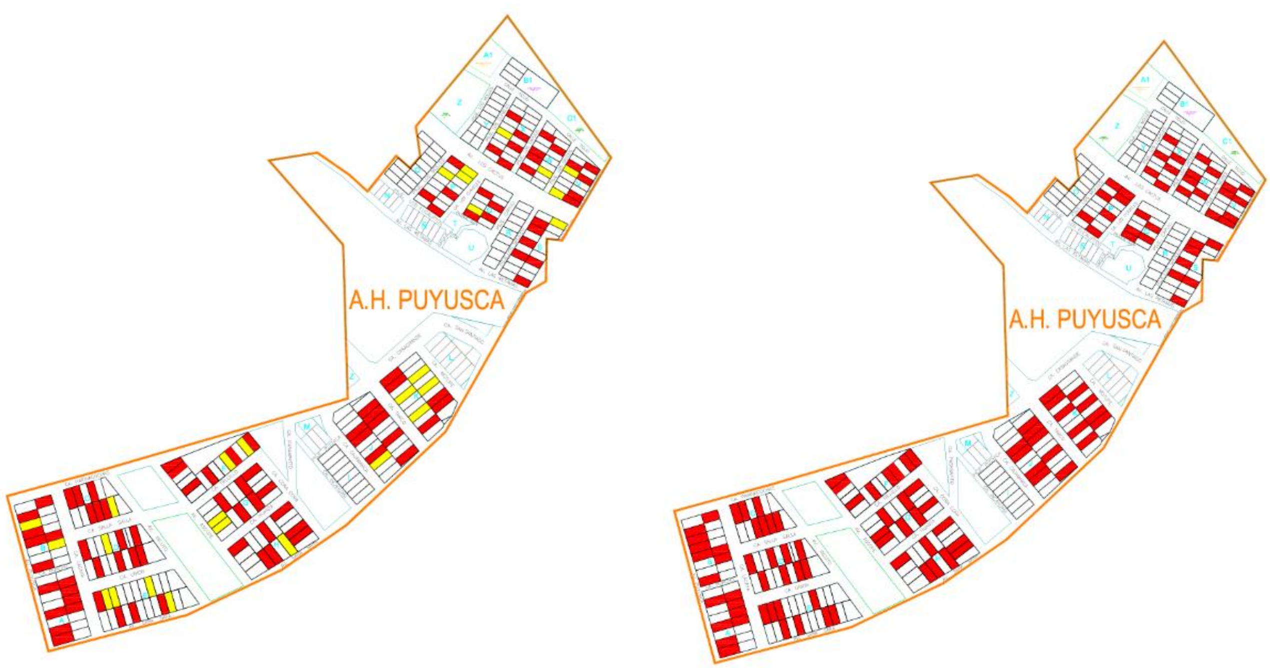

Fig. 6. Seismic Vulnerability Maps According to Benedetti-Petrini (left) and FEMA P-154 (right)

Next, Figure 7 displays the ETABS models of the three selected dwellings, and Figure 8 illustrates the interstory displacements and drifts obtained from the structural analyses.

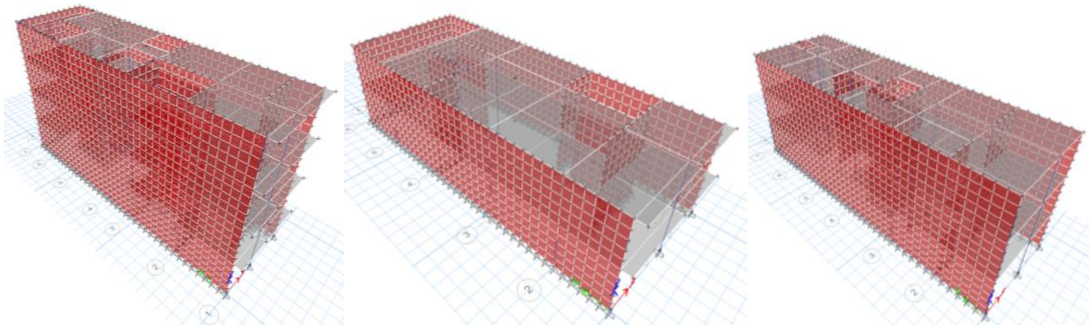

Fig. 7. ETABS Models of Dwellings: V01 (left), V02 – 2 stories (center), V03 – 3 stories (right)

Story	Diaphragm	Output Case	Step Type	UX m	Desplaz. Relativo	Altura entrepiso	Deriva Elástica	Deriva Inelástica
Techo 4° nivel	D4	SDX	Max	0.009269	0.00240	2.80000	0.00086	0.00218
Techo 3° nivel	D3	SDX	Max	0.00687	0.00271	2.80000	0.00097	0.00246
Techo 2° nivel	D2	SDX	Max	0.004165	0.00252	2.80000	0.00090	0.00230
Techo 1° nivel	D1	SDX	Max	0.001644	0.00164	2.80000	0.00059	0.00150

Story	Diaphragm	Output Case	Step Type	UX m	Desplaz. Relativo	Altura entrepiso	Deriva Elástica	Deriva Inelástica
Techo 4° nivel	D4	SDY	Max	0.00215	0.00033	2.8	0.00012	0.00030
Techo 3° nivel	D3	SDY	Max	0.00182	0.00052	2.8	0.00019	0.00048
Techo 2° nivel	D2	SDY	Max	0.00129	0.00065	2.8	0.00023	0.00059
Techo 1° nivel	D1	SDY	Max	0.00065	0.00065	2.8	0.00023	0.00059

Fig. 8. Displacement and Drift: Dwelling V01 in X-Direction (left), V01 in Y-Direction (right)

For dwelling V01 in the "X" direction, the maximum absolute displacement was found to be 0.009269 at the fourth story, with a peak inelastic drift ratio of 0.00246. In the "Y" direction, the maximum drift recorded was 0.00059. Both values remained below the allowable drift limit of 0.005, as specified by the Peruvian Seismic Design Code E.030.

Story	Diaphragm	Output Case	Step Type	UX m	Desplaz. Relativo	Altura entrepiso	Deriva Elástica	Deriva Inelástica
Techo 2° nivel	D2	SDX	Max	0.00194	0.00094	2.80000	0.00034	0.00086
Techo 1° nivel	D1	SDX	Max	0.00100	0.00100	2.80000	0.00036	0.00091

Story	Diaphragm	Output Case	Step Type	UY m	Desplaz. Relativo	Altura entrepiso	Deriva Elástica	Deriva Inelástica
Techo 2° nivel	D2	SDY	Max	0.000601	0.00024	2.8	0.00008	0.00022
Techo 1° nivel	D1	SDY	Max	0.000364	0.00036	2.8	0.00013	0.00033

Fig. 9. Displacement and Drift: Dwelling V02 in X-Direction (left), V02 in Y-Direction (right)

For dwelling V02 (Figure 9), the maximum displacement in the "X" direction was 0.00194 on the second story, with a corresponding inelastic drift of 0.00091. In the "Y" direction, the maximum drift was 0.00033—again remaining within permissible limits.

Story	Diaphragm	Output Case	Step Type	UX m	Desplaz. Relativo	Altura entrepiso	Deriva Elástica	Deriva Inelástica
Techo 3° nivel	D3	SDX	Max	0.00427	0.00146	2.80000	0.00052	0.00133
Techo 2° nivel	D2	SDX	Max	0.00281	0.00161	2.80000	0.00058	0.00147
Techo 1° nivel	D1	SDX	Max	0.00120	0.00120	2.80000	0.00043	0.00109

Story	Diaphragm	Output Case	Step Type	UY m	Desplaz. Relativo	Altura entrepiso	Deriva Elástica	Deriva Inelástica
Techo 3° nivel	D3	SDY	Max	0.00145	0.00032	2.8	0.00011	0.00029
Techo 2° nivel	D2	SDY	Max	0.00114	0.00053	2.8	0.00019	0.00048
Techo 1° nivel	D1	SDY	Max	0.00061	0.00061	2.8	0.00022	0.00055

Fig. 10. Displacement and Drift: Dwelling V03 in X-Direction (left), V03 in Y-Direction (right)

For dwelling V03 (Figure 10), the "X" direction exhibited a maximum absolute displacement of 0.00427 on the third story, with a peak inelastic drift of 0.00147. In the "Y" direction, the maximum drift was 0.00055. Both results remained below the limit prescribed by E.030.

A structural retrofitting strategy using welded wire mesh (WWM) was proposed to mitigate diagonal cracking in the masonry walls. According to E.070, under moderate seismic loading, the applied shear force (Ve) should not exceed 55% of the shear capacity at cracking (Vm). Figure 11 shows the results of this verification.

Muro	Pg (kg)	Ve-X (kg)	Me-X (kg-m)	Ve-Y (kg)	Me-Y (kg-m)	Ve (kg)	Me (kg-m)	$\frac{L}{0.8H}$	α	Vm (kg)	$V_e \leq 0.55V_m$
MX-1	10118.69	22098.62	32987.56	3.14	8.83	22098.62	32987.56	2.54	1.000	33390.80	FISURADO
MX-2	5075.88	8071.69	5946.01	9.57	4.24	8071.69	5946.01	0.99	0.991	13172.56	FISURADO
MX-3	6996.54	13533.96	10164.16	14.33	7.61	13533.96	10164.16	1.21	1.000	27691.20	NO FISURADO
MX-4	5528.43	9625.25	7410.78	5.51	5.42	9625.25	7410.78	0.99	0.991	13276.65	FISURADO
MX-5	9053.20	9261.46	14980.06	40.41	20.42	9261.46	14980.06	0.82	0.819	16576.70	FISURADO
MX-6	16609.37	33126.56	42556.62	24.90	8.01	33126.56	42556.62	1.44	1.000	35025.41	FISURADO
MY-1	50575.87	114.47	67.03	42014.87	83811.46	42014.87	83811.46	8.60	1.000	116669.20	NO FISURADO
MY-2	11358.32	32.55	6.56	4786.52	4242.99	4786.52	4242.99	1.47	1.000	20513.41	NO FISURADO
MY-3	14315.34	17.07	17.18	6865.18	6238.24	6865.18	6238.24	1.85	1.000	25932.03	NO FISURADO
MY-4	57836.95	81.64	77.07	40252.59	75029.50	40252.59	75029.5	8.60	1.000	118339.25	NO FISURADO

Muro	Pg (kg)	Ve-X (kg)	Me-X (kg-m)	Ve-Y (kg)	Me-Y (kg-m)	Ve (kg)	Me (kg-m)	$\frac{L}{0.8H}$	α	Vm (kg)	$V_e \leq 0.55V_m$
MX-1	3305.9	19749.76	40901.43	9.08	14.92	19749.76	40901.43	3.527	1	42353.86	NO FISURADO
MX-2	8077.29	6900.9	10671.93	28.69	50.66	6900.90	10671.93	1.138	1	15283.53	NO FISURADO
MX-3	5993.13	10999.9	17449.69	12.66	19.27	10999.90	17449.69	1.205	1	15593.92	FISURADO
MX-4	6040.91	20203.46	35545.53	15.39	25.8	20203.46	35545.53	1.509	1	32874.11	FISURADO
MY-1	47199.38	152.17	63685.72	22275.37	10.86	22275.37	63685.72	8.795	1	114576.36	NO FISURADO
MY-2	6595.37	20.44	416.21	2674.44	4.81	2674.44	416.21	1.339	1	17311.94	NO FISURADO
MY-3	5567.73	19.18	1014.51	2600.28	4.84	2600.28	1014.51	1.339	1	17075.58	NO FISURADO
MY-4	5910.49	29.37	1107.85	2859.57	4.28	2859.57	1107.85	1.406	1	17944.16	NO FISURADO
MY-5	39089.79	193.09	40311.5	19463	10.77	19463.00	40311.5	8.795	1	112711.15	NO FISURADO

Muro	Pg (kg)	Ve-X (kg)	Me-X (kg-m)	Ve-Y (kg)	Me-Y (kg-m)	Ve (kg)	Me (kg-m)	$\frac{L}{0.8H}$	α	Vm (kg)	$V_e \leq 0.55V_m$
MX-1	12069.20	22522.54	49678.67	42.47	71.38	22522.54	49678.67	2.701	1.000	34629.17	FISURADO
MX-2	7535.41	12917.40	22895.25	29.33	43.07	12917.40	22895.25	1.464	1.000	19002.34	FISURADO
MX-3	5888.62	13706.11	24349.45	20.02	32.90	13706.11	24349.45	1.348	1.000	29485.68	NO FISURADO
MX-4	5435.72	15206.40	26814.00	19.77	32.66	15206.40	26814.00	1.348	1.000	29381.52	NO FISURADO
MX-5	3838.03	10915.87	17050.31	12.48	20.66	10915.87	17050.31	0.951	0.951	19749.36	FISURADO
MX-6	8285.62	19031.85	32411.57	20.05	32.36	19031.85	32411.57	1.286	1.000	28732.89	FISURADO
MY-1	49198.01	351.47	642.97	48420.44	119250.44	48420.44	119250.44	9.375	1.000	121880.54	NO FISURADO
MY-2	4958.11	45.44	76.57	4173.16	6466.65	4173.16	6466.65	1.080	1.000	13881.67	NO FISURADO
MY-3	49448.26	397.43	685.95	44103.97	118309.21	44103.97	118309.21	9.375	1.000	121938.10	NO FISURADO

Fig. 11. Cracking Verification: Dwelling V01 (top left), V02 (top right), and V03 (bottom center)

In dwelling V01, the cracked walls in the "X" direction were MX-1, MX-2, MX-4, MX-5, and MX-6. In V02, the affected walls were MX-3 and MX-4, and in V03, the damaged walls included MX-1, MX-2, MX-5, and MX-6. Walls oriented in the "Y" direction did not require retrofitting since their admissible shear strength exceeded the applied seismic demand (Ve). The analysis was limited to first-story walls, as these are the most structurally vulnerable.

Muro	Espesor (m)	Longitud (m)	v'm (kgf/cm2)	Pg (ton)	H (m)	alfa	Vm1 (tonf)	0.55 vm	Ve1	Condición
MX-1	0.19	5.90	8.10	10.12	2.80	1.00	47.73	26.25	22.10	Ok
MX-2	0.19	2.30	8.10	5.08	2.80	1.00	18.87	10.38	8.07	Ok
MX-3	0.29	2.80	8.10	7.00	2.80	1.00	34.50	18.97	13.53	Ok
MX-4	0.19	2.30	8.10	5.53	2.80	1.00	18.97	10.43	9.63	Ok
MX-5	0.29	1.90	8.10	9.05	2.80	0.85	21.01	11.56	9.26	Ok

Muro	Espesor (m)	Longitud (m)	v'm (kgf/cm2)	Pg (ton)	H (m)	alfa	Vm1 (tonf)	0.55 vm	Ve1	Condición
MX-1	0.19	7.90	8.10	3.31	2.80	1.00	61.55	33.85	19.75	Ok
MX-2	0.19	2.55	8.10	8.08	2.80	1.00	21.48	11.81	6.90	Ok
MX-3	0.19	2.70	8.10	5.99	2.80	1.00	22.15	12.19	11.00	Ok
MX-4	0.29	3.38	8.10	6.04	2.80	1.00	41.09	22.60	20.20	Ok

Muro	Espesor (m)	Longitud (m)	v'm (kgf/cm2)	Pg (ton)	H (m)	alfa	Vm1 (tonf)	0.55 vm	Ve1	Condición
MX-1	0.19	6.05	8.10	12.07	2.80	1.00	49.33	27.13	22.52	Ok
MX-2	0.19	3.28	8.10	7.54	2.80	1.00	26.97	14.84	12.92	Ok
MX-3	0.29	3.02	8.10	5.89	2.80	1.00	36.82	20.25	13.71	Ok
MX-4	0.29	3.02	8.10	5.44	2.80	1.00	36.72	20.20	15.21	Ok
MX-5	0.29	2.13	8.10	3.84	2.80	0.95	24.67	13.57	10.92	Ok
MX-6	0.29	2.88	8.10	8.29	2.80	1.00	35.73	19.65	19.03	Ok

Fig. 12. Strengthening with Welded Wire Mesh: Dwelling V01 (top left), V02 (top right), and V03 (bottom center)

Figure 12 presents the proposed retrofitting intervention using WWM, where an equivalent thickness increase of 3.00 cm per face was applied. This modification increased the thickness of stretcher walls from 13 cm to 19 cm, and header walls from 23 cm to 29 cm, thereby enhancing the shear strength (Vm) of the retrofitted walls. The updated values satisfied the design condition Ve < 0.55Vm.

Muro	Vm (tn) sin malla electrosoldada	Vm (tn) con malla electrosoldada	Variación (%)
MX-1	33.39	47.73	30.04
MX-2	13.17	18.87	30.18
MX-4	13.28	18.97	30.01

Muro	Vm (tn) sin malla electrosoldada	Vm (tn) con malla electrosoldada	Variación (%)
MX-3	15.59	22.15	29.61
MX-4	32.87	41.09	19.99

Muro	Vm (tn) sin malla electrosoldada	Vm (tn) con malla electrosoldada	Variación (%)
MX-1	34.63	49.33	29.80
MX-2	19.00	26.97	29.55
MX-5	19.75	24.67	19.95
MX-6	28.73	35.73	19.59

Fig. 13. Comparison of stresses without and with welded wire mesh: house V01 (top left), house V02 (top right), and house V03 (bottom center)

Figure 13 compares the shear capacities of the walls before and after retrofitting. For V01, wall MX-1 initially had a Vm of 33.39 t, which increased by 30% to 47.73 t after retrofitting. Similar increases were observed in MX-2 and MX-4, with final values of 30.18 t and 30.10 t, respectively. In V02, the increases in Vm for MX-3 and MX-4 were 29.61% and 19.99%, respectively. In V03, the walls MX-5 and MX-6 improved by 19%, while MX-1 and MX-2 each showed an increase of 29%. These results confirm the effectiveness of WWM in enhancing shear resistance against seismic demand.

Story	Deriva Inelástica		Variación
	sin malla	malla elect.	%
Techo 4° nivel	0.00218	0.00215	-1.57
Techo 3° nivel	0.00246	0.00239	-3.28
Techo 2° nivel	0.00230	0.00221	-3.70
Techo 1° nivel	0.00150	0.00138	-8.30

Story	Deriva Inelástica		Incremento
	sin malla	malla elect.	%
Techo 2° nivel	0.00086	0.00079	-9.13
Techo 1° nivel	0.00091	0.00080	-13.51

Story	Deriva Inelástica		Variación
	sin malla	malla elect.	%
Techo 3° nivel	0.00133	0.00122	-8.79
Techo 2° nivel	0.00147	0.00130	-12.64
Techo 1° nivel	0.00109	0.00093	-17.42

Fig. 14. Comparison of inelastic drifts without and with welded wire mesh: house V01 (left), house V02 (center), and house V03 (right)

Finally, Figure 14 presents a comparative analysis of inelastic drifts before and after retrofitting. In V01 (4 stories), the maximum drift at the first story was reduced by 8.30% due to increased stiffness from the additional wall thickness. In V02 (2 stories), the first-story drift decreased from 0.00091 to 0.00080 (a 13.51% reduction). In V03 (3 stories), reductions of 8.79%, 12.64%, and 17.42% were recorded for the third, second, and first stories, respectively. These findings confirm that WWM retrofitting effectively enhances masonry wall stiffness and reduces seismic drift demands.

4. Conclusions

The seismic vulnerability degree was determined by applying the Benedetti-Petrini method. It was found that, out of the total evaluated buildings, approximately 80.83% are highly vulnerable, 19.17% have a medium vulnerability level, and finally, 0.00% fall into the low vulnerability category. These percentages provide insight into how vulnerable the houses in Puyusca informal settlement are. Using the FEMA P-154 methodology, which considers only two levels—vulnerable or not vulnerable, the results indicate that 100.00% of the houses are vulnerable to seismic events.

From the structural assessment of the three houses, it was identified that they have issues related to low wall density, with cracked walls occurring more frequently along the shorter direction of the houses. Furthermore, it was determined that they exhibit problems of plan torsional irregularity due to having few walls on the front side. However, the E.030 code allows for irregularity in seismic zone 4.

Masonry walls showing signs of cracking under moderate seismic loading were retrofitted with welded wire mesh. For dwelling V01, walls MX-1, MX-2, and MX-4 showed a 30% increase in shear strength (Vm), making them capable of resisting the seismic-induced shear forces. In dwelling V02, walls MX-3 and MX-4 exhibited Vm increases of 30% and 19%, respectively. In dwelling V03, strengthened walls MX-1, MX-2, MX-5, and MX-6 also demonstrated significant improvements in shear resistance. Inelastic drift ratios obtained from the unreinforced and reinforced models showed substantial reductions across all three buildings. The reductions were most notable at the first story: 8.30% for V01, 13.51% for V02, and 17.42% for V03. These results underscore the effectiveness of welded wire mesh in increasing stiffness and improving seismic performance of confined masonry structures.

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