Revista Iberoamericana para la Investigación y el Desarrollo Educativo
ISSN 2007 - 7467

https://doi.org/10.23913/ride.v16i32.2931

Scientific article

Desarrollo y aplicación de una herramienta electrónica para la docencia en Ingeniería Civil

Development and application of an electronic tool for teaching in Civil Engineering

Desenvolvimento e aplicação de uma ferramenta eletrônica para o ensino em Engenharia Civil

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Revista Iberoamericana para la Investigación y el Desarrollo Educativo
ISSN 2007 - 7467

Resumen

Este trabajo presenta el desarrollo, aplicación y evaluación de una herramienta electrónica interactiva implementada en Microsoft Excel para apoyar la docencia en Ingeniería Civil, orientada al análisis y diseño de muros de mampostería confinada con base en la normatividad vigente. La herramienta integra fundamentos teóricos, procedimientos automatizados de cálculo y comentarios explicativos para fortalecer la comprensión técnica y promover el aprendizaje autónomo.

Los resultados cuantitativos muestran que el uso de la herramienta redujo en promedio 43 % el tiempo de resolución de ejercicios. Asimismo, 86 % de los participantes reportó una mejora en la comprensión del comportamiento de los muros de mampostería confinada; 90 % manifestó no conocer herramientas gratuitas con características equivalentes y 72 % expresó su intención de incorporarla en su práctica profesional. La organización de la hoja de cálculo y los comentarios de apoyo alcanzaron niveles de aceptación de 92 % y 90 %, respectivamente. La valoración de la estructura general del recurso obtuvo una media de 4.34 y desviación estándar de 0.91. La evaluación global del recurso obtuvo una media de 9.54 y una desviación estándar de 0.71.

Se concluye que la herramienta constituye un recurso didáctico accesible, funcional y pertinente, que favorece la integración entre tecnología, pedagogía y normatividad aplicable. Su uso resulta relevante en contextos de educación superior y en entornos académicos con acceso limitado a software especializado.

Palabras clave: aprendizaje activo; docencia; herramienta digital interactiva; ingeniería civil; mampostería confinada.

Abstract

This paper presents the development, implementation, and evaluation of an interactive electronic tool created in Microsoft Excel to support Civil Engineering education, focused on the analysis and design of confined masonry walls in accordance with current regulations. The tool integrates theoretical foundations, automated calculation procedures, and explanatory comments to strengthen technical understanding and promote autonomous learning.

Quantitative results indicate that the use of the tool reduced exercise-solving time by an average of 43%. In addition, 86% of participants reported better understanding of confined

masonry wall behavior; 90% stated that they were not aware of free tools with equivalent features, and 72% expressed their intention to incorporate it into their professional practice. The spreadsheet organization and support comments achieved acceptance levels of 92% and 90%, respectively. The general structure of the resource obtained a mean score of 4.34 and a standard deviation of 0.91. The overall evaluation of the tool reached a mean score of 9.54, with a standard deviation of 0.71.

It is concluded that the proposed tool represents an accessible, functional, and relevant didactic resource that supports the integration of technology, pedagogy, and applicable regulations. Its use is relevant in higher education contexts and in academic environments with limited access to specialized software.

Keywords: active learning; teaching; interactive digital tool; civil engineering; confined masonry.

Resumo

Este artigo apresenta o desenvolvimento, a aplicação e a avaliação de uma ferramenta eletrônica interativa implementada no Microsoft Excel para auxiliar o ensino de Engenharia Civil, com foco específico na análise e no dimensionamento de paredes de alvenaria confinada, de acordo com as normas vigentes. A ferramenta integra fundamentos teóricos, procedimentos de cálculo automatizados e comentários explicativos para fortalecer a compreensão técnica e promover a aprendizagem independente.

Os resultados quantitativos mostram que o uso da ferramenta reduziu o tempo necessário para a resolução dos exercícios em uma média de 43%. Além disso, 86% dos participantes relataram uma melhor compreensão do comportamento de paredes de alvenaria confinada; 90% afirmaram desconhecer qualquer ferramenta gratuita com recursos equivalentes e 72% expressaram a intenção de incorporá-la à sua prática profissional. A organização da planilha e os comentários explicativos alcançaram níveis de aceitação de 92% e 90%, respectivamente. A estrutura geral do recurso foi avaliada com uma média de 4,34 e um desvio padrão de 0,91. A avaliação geral do recurso obteve uma pontuação média de 9,54 e um desvio padrão de 0,71.

Conclui-se que a ferramenta constitui um recurso educacional acessível, funcional e relevante que promove a integração da tecnologia, da pedagogia e das normas aplicáveis. Seu uso é

particularmente relevante em contextos de ensino superior e em ambientes acadêmicos com acesso limitado a softwares especializados.

Palavras-chave: aprendizagem ativa; ensino; ferramenta digital interativa; engenharia civil; alvenaria confinada.

Date Received: October 2025 **Date Accepted:** April 2026

Introduction

Higher education in Mexico faces a constantly evolving technological environment, in which the development of specialized tools seeks to improve the efficiency and effectiveness of the teaching-learning process in complex technical areas. Recent studies highlight the implementation of digital resources that promote collaborative learning and interaction between teachers and students. For example, Díaz et al. (2023) indicate that virtual environments increase the efficiency of training processes, while Coca and Benítez (2023) demonstrate that GeoGebra improves the understanding of mathematical concepts. Likewise, tools such as GNU-Octave and Raspberry Pi have proven useful in simulations of nonlinear systems (Torres et al., 2019).

Despite these advances, in Civil Engineering there are still limited free access tools that allow strengthening practical training through simulation, analysis and normative application, especially in the design and review of confined masonry walls, a material widely used in national construction (Sunley, 2024).

The use of digital resources in teaching can strengthen instruction and foster meaningful learning. Brioso, Calderón, and Fuentes (2023) highlight that the incorporation of educational technology contributes to updating curricula and increasing student motivation. In particular, the analysis and design of masonry walls require teaching tools that facilitate the understanding of regulatory criteria and strengthen the training of professionals capable of designing safer and more efficient structures.

According to the National Seismological Service, the south-central region of Mexico has experienced large-magnitude seismic events that have affected confined and unreinforced masonry buildings (SSN, 1985, 2012, 2017; Flores et al., 2012). Figure 1 shows the location of relevant earthquakes that occurred in 1985, 2012, and 2017, while Table 1 summarizes their main seismic characteristics.

The present study aims to develop, apply and evaluate an interactive electronic tool in Microsoft Excel for learning the design and review of confined masonry walls.

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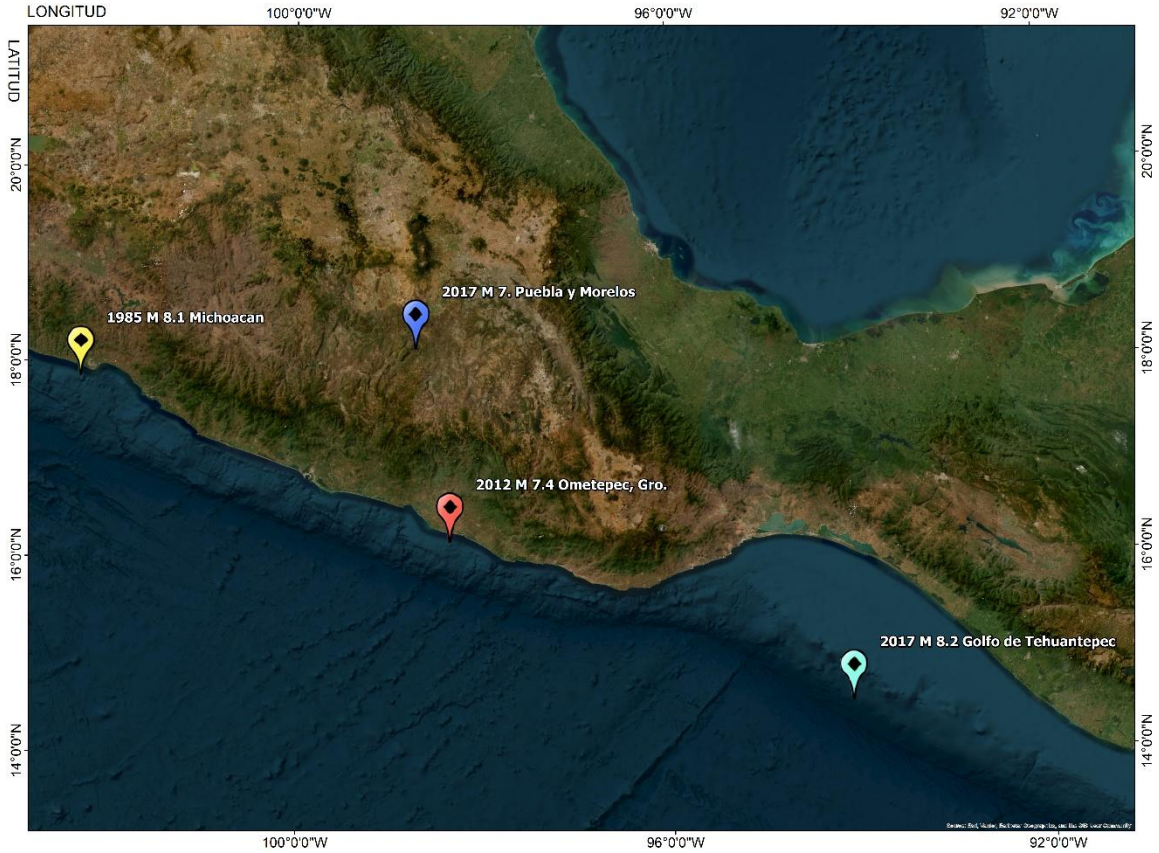
ISSN 2007 - 7467

Figure 1. Location of earthquakes with magnitudes *7.1 ≤ 8.2.*



Source: National Seismological Service SSN (1985–2017).

Table 1. Relevant earthquakes with magnitude *7.1 ≤ 8.2.*

Date	Hour	Mag.	Lat. ° (N)	Long. ° (W)	Prof. (Km)	Epicenter
19/09/1985	07:17	8.1	18.11	-102.32	15	Michoacán, near Lázaro Cárdenas
7/09/2017	23:49	8.2	14.76	-94.10	45	To the Gulf of Tehuantepec
19/09/2017	13:14	7.1	18.40	-98.72	12	Between Puebla and Morelos
20/03/2012	12:02	7.4	16.42	-98.36	15	Ometepec, Guerrero

Source: National Seismological Service (SSN).

Methodology

The study was structured in three main stages. In the first, an interactive spreadsheet was developed in Microsoft Excel with automated formulas for the analysis and design of confined masonry walls, based on current regulations (Government of Mexico City, 2023).

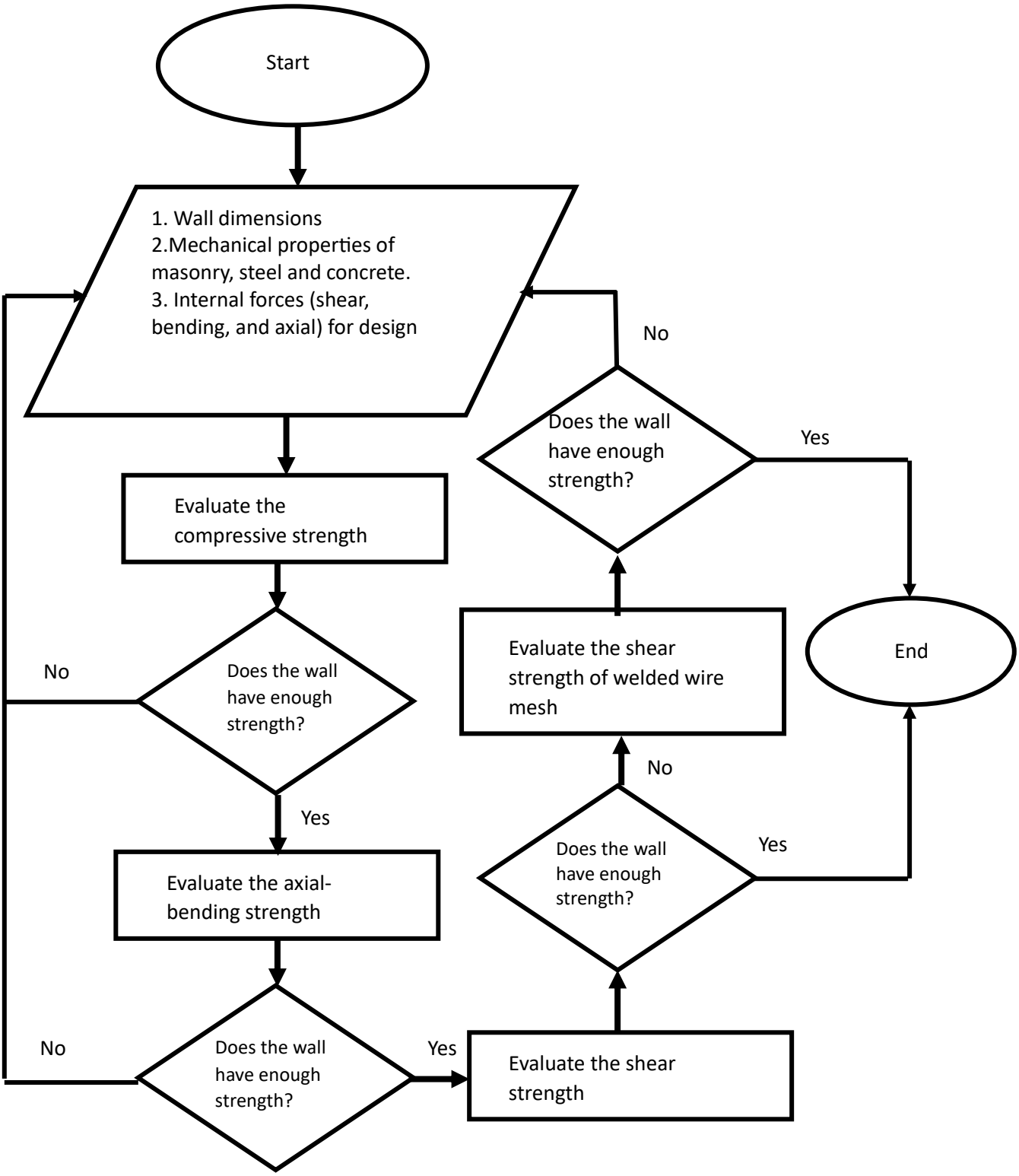
In the second stage, an evaluation instrument was designed consisting of seven five-level Likert-type items to assess the efficiency, clarity, professional applicability, and academic relevance of the developed tool.

In the third stage, a pilot application was conducted with the participation of 50 people: 21 students, 25 professionals, and four participants linked to the construction sector. This phase allowed for the evaluation of the functionality and general acceptance of the proposed resource.

a) Development of the electronic tool

Figure **2** presents the general operating algorithm of the tool.

Figure 2. Basic algorithm for developing the tool.



Source: Authors' own elaboration.

Figure **3** shows the main interface of the spreadsheet used for structural analysis.

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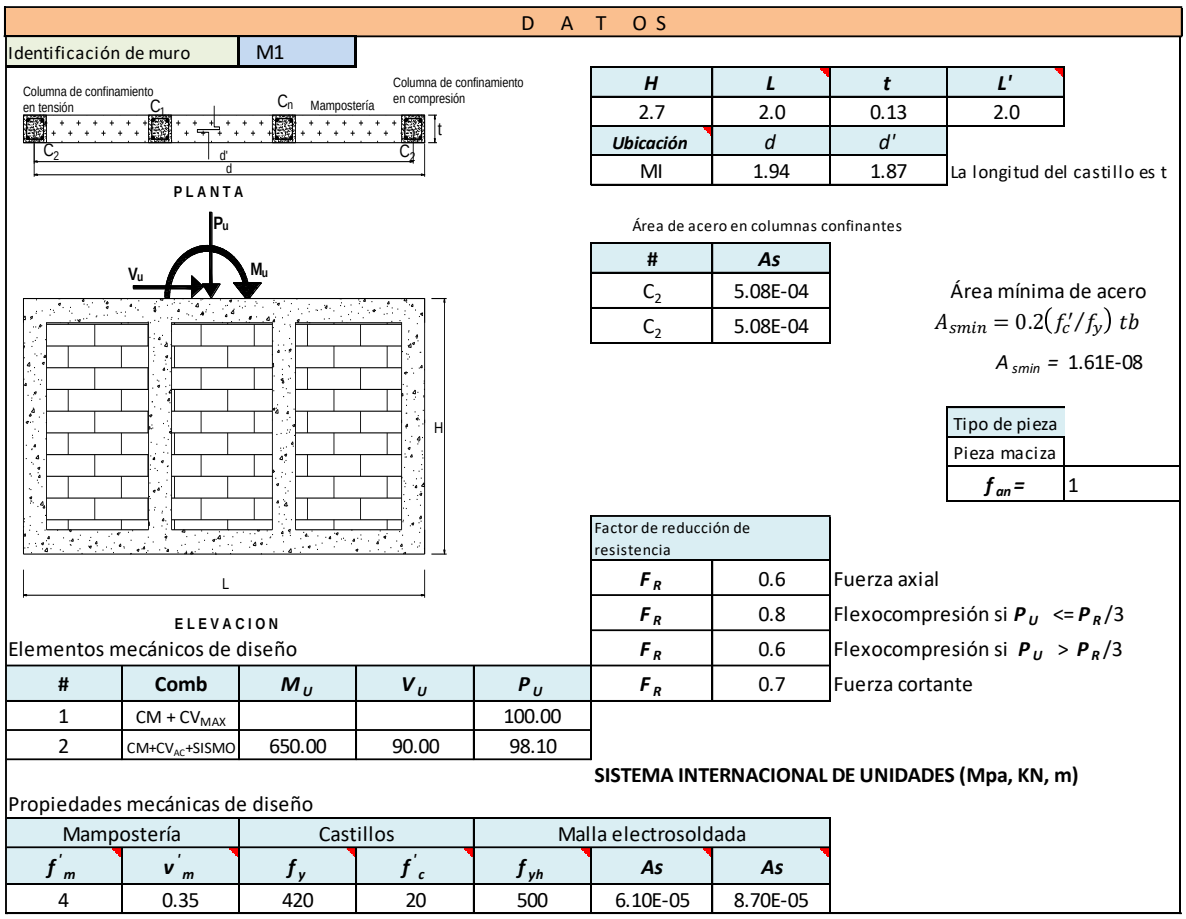
Figure 3. Spreadsheet of the wall design tool (first page).



D A T O S

Identificación de muro: M1

H	L	t	L'
2.7	2.0	0.13	2.0
Ubicación	d	d'	
MI	1.94	1.87	

La longitud del castillo es t

Área de acero en columnas confinantes

#	As
C_2	5.08E-04
C_2	5.08E-04

Área mínima de acero

$A_{smin} = 0.2(f_c'/f_y)\ tb$

A_{smin} = 1.61E-08

Tipo de pieza	
Pieza maciza	
f_{an}=	1

Factor de reducción de resistencia		
F_R	0.6	Fuerza axial
F_R	0.8	Flexocompresión si P_U <= P_R/3
F_R	0.6	Flexocompresión si P_U > P_R/3
F_R	0.7	Fuerza cortante

Elementos mecánicos de diseño

#	Comb	M_U	V_U	P_U
1	CM + CV_{MAX}			100.00
2	CM+CV_{AC}+SISMO	650.00	90.00	98.10

SISTEMA INTERNACIONAL DE UNIDADES (Mpa, KN, m)

Propiedades mecánicas de diseño

Mampostería		Castillos		Malla electrosoldada		
f'_m	v'_m	f_y	f'_c	f_{yh}	As	As
4	0.35	420	20	500	6.10E-05	8.70E-05

Source: Authors' own elaboration.

Design of the assessment instrument

Figure **4** presents the assessment instrument applied to the participants. The internal consistency of the instrument was verified using Cronbach's alpha coefficient, obtaining a value suitable for exploratory purposes.

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Figure 4. Assessment instrument (survey).

Ocupación

Estudiante		Profesionista		Otro
Ingeniería	Arquitectura	Ingeniero	Arquitecto	
○	○	○	○	○

¿Conoce usted alguna aplicación con las mismas características (construcciones simples, tipo de mampostería y sin costo)?

Si	No
○	○

En una escala de 1-5, ¿Cuál es el impacto de esta herramienta para comprender el análisis y diseño de construcciones de mampostería confinada con distribuciones arquitectónicas simples?

Bajo/1	2	3	4	Muy alto/5
○	○	○	○	○

En una escala de 1-5, ¿Considerando las características de las construcciones estudiadas, que tan frecuentemente utilizaría esta hoja de cálculo en su profesión o estudio?

Nunca/1	2	3	4	Muy frecuente/5
○	○	○	○	○

En una escala de 1-5, ¿Los comentarios o ayudas existentes en la hoja de cálculo son adecuados?

Inadecuados/1	2	3	4	Muy adecuados/5
○	○	○	○	○

En una escala de 1-5, ¿Las doce hojas que integran la aplicación son suficientes?

Insuficientes/1	2	3	4	Suficientes/5
○	○	○	○	○

Finalmente, en una escala de 6-10, ¿Cuál es la calificación de esta hoja de cálculo?

6	7	8	9	10
○	○	○	○	○

Cualquier otro comentario enviarlo a: astizapa@uagro.mx

Source: Authors' own elaboration.

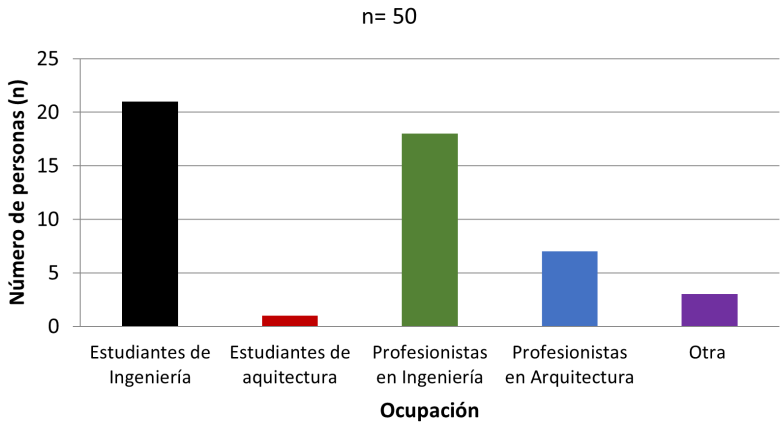
b) Measurement of academic and professional perception

The responses obtained were analyzed using descriptive statistics with frequencies, percentages, arithmetic means and standard deviation.

Results

Figure **5** shows the distribution of participants by occupation. The instrument was answered by 50 participants.

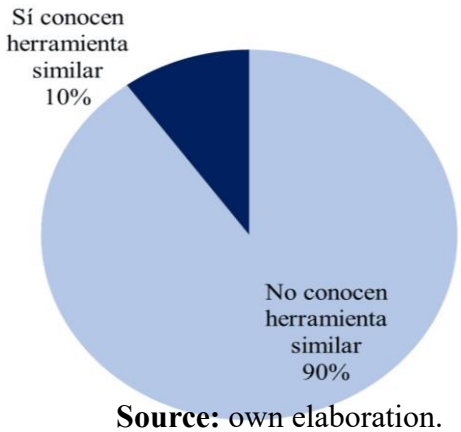
Figure 5. Distribution and occupation of the participants.



Source: own elaboration.

In the second question, 90% of participants indicated they were unaware of any other free tool with equivalent features, while 10% responded affirmatively. Figure **6** presents these results.

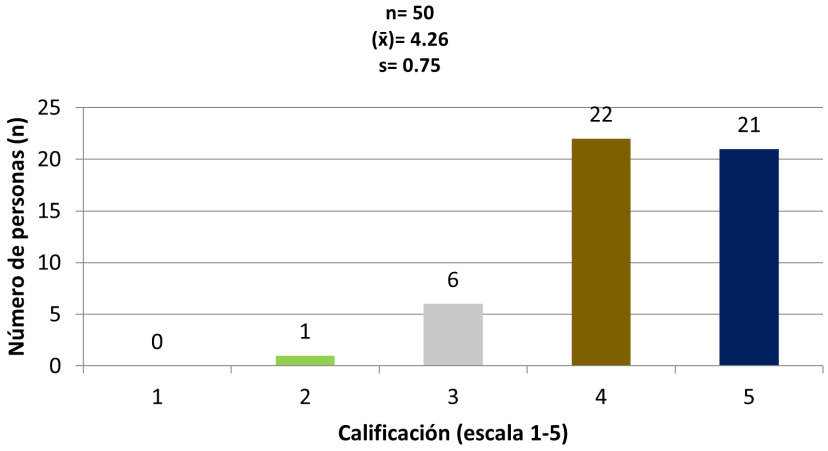
Figure 6. Percentage of knowledge of the electronic tool.



Source: own elaboration.

Figure **7** shows the results related to understanding the structural analysis of confined masonry walls. A mean of 4.26 and a standard deviation of 0.75 were obtained.

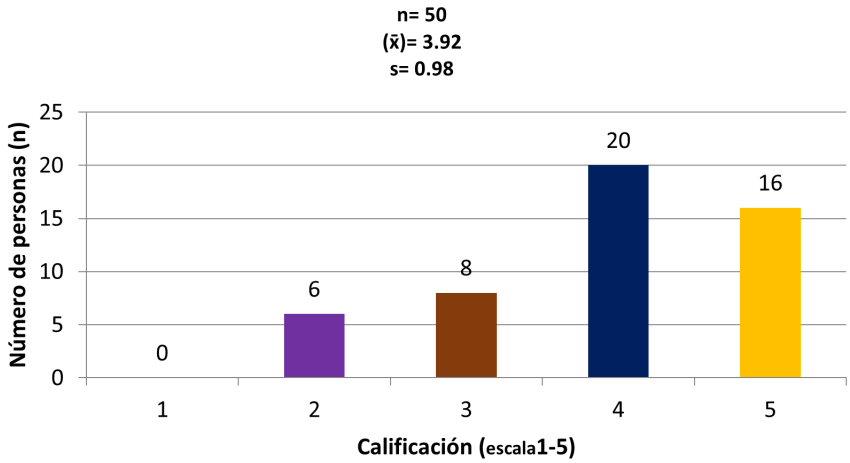
Figure 7. Results and number of participants who evaluated the tool.



Source: own elaboration.

Figure **8** presents the intended future use of the tool in professional practice, with a mean of 3.92 and a standard deviation of 0.98.

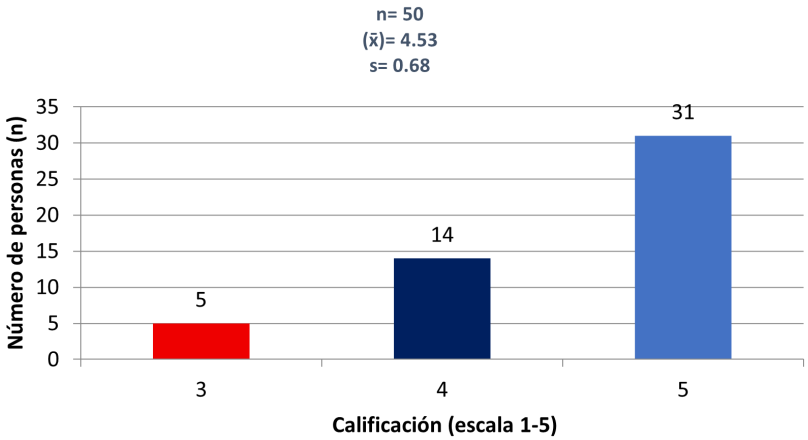
Figure 8. Rating results of the masonry wall design tool.



Source: own elaboration.

Figure **9** shows the evaluation of the clarity of comments and help integrated into the spreadsheet, with a mean of 4.53 and a standard deviation of 0.68.

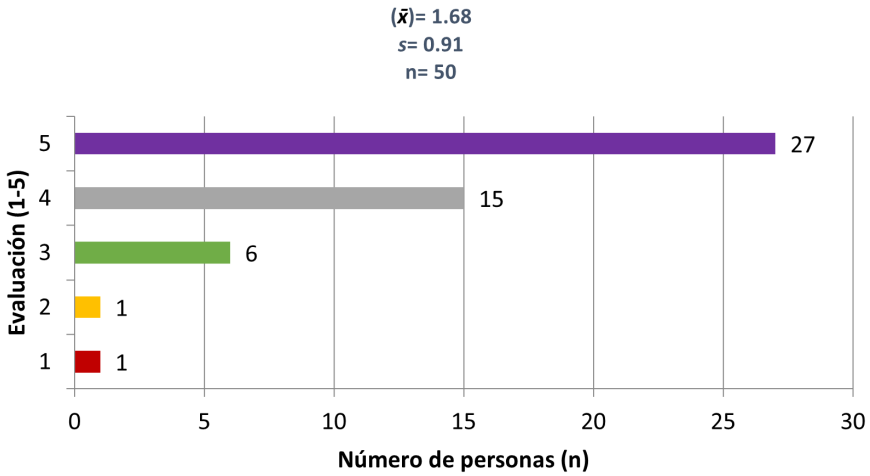
Figure 9. Results of the assessment of the tool's relevance.



Source: own elaboration

Figure **10** presents the overall assessment of the tool's structural organization. A mean of 4.34 and a standard deviation of 0.91 were obtained, with a predominance of high ratings from the participants.

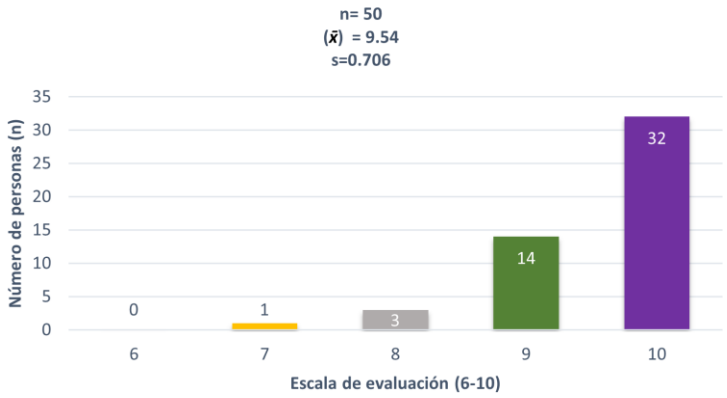
Figure 10. Evaluation results of the application of the instrument (survey).



Source: own elaboration.

Finally, **Figure 11** shows the overall evaluation of the resource, with a mean of 9.54 and a standard deviation of 0.71.

Figure 11. Results of the overall evaluation of the tool.



Source: own elaboration.

Discussion

The results obtained suggest that the interactive electronic tool developed in Microsoft Excel can contribute to improving the efficiency of learning in Civil Engineering, particularly in the analysis and design of confined masonry walls.

The acceptance observed by users coincides with previous studies that highlight the use of digital tools as support for autonomous learning, problem solving and the integration between theory and professional practice (Brioso et al., 2023; Melgoza and Fabián, 2023).

However, the results should be interpreted considering the sample size and the exploratory nature of the study. Future research could expand the number of participants and apply the tool in other academic and professional contexts.

Conclusions

The results obtained indicate that the interactive electronic tool developed in Microsoft Excel constitutes a useful didactic resource to strengthen the teaching-learning process in Civil Engineering.

The evaluation revealed a positive perception among users, particularly regarding clarity, usefulness, and professional applicability. It also promotes the integration of theory, current regulations, and professional practice.

Its accessible nature positions it as a relevant alternative for academic contexts with limited access to specialized software and represents an innovative option for contemporary technical training.

Contributions to future lines of research

Higher education institutions require similar digital tools to strengthen the teaching and learning process. The proposed tool offers the possibility of updates as the Complementary Technical Standards evolve and can be adapted to other areas of knowledge related to Civil Engineering.

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Software	Imelda López Valle, Gerardo Altamirano de la Cruz (supports), Sulpicio Sánchez Tizapa (same).
Validation	Imelda López Valle, Sulpicio Sánchez Tizapa, Gerardo Altamirano de la Cruz, Roberto Arroyo-Matus (same)
Formal analysis	Imelda López Valle (principal), Sulpicio Sánchez Tizapa (principal), Alfredo Cuevas-Sandoval (supporting),
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