

Enhancing Structural Design Education with Excel: A Case Study on Rebar Computation for Simply Supported Slabs

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Abstract

Conventional approaches to teaching structural design often rely on manual calculations, which can be laborious and challenging for learners. This study investigates the integration of Excel as an educational tool to improve student engagement, enhance algorithmic efficiency, and reinforce conceptual comprehension of rebar computation in simply supported slabs. A case study approach was adopted in which students were introduced to an Excel-based spreadsheet for rebar computation. The high-end tool automates reinforcement calculations, allowing students to envision how different structural parameters perform dynamically in real-time. Data was collected through a mixed-methods approach involving instructor observations, structured surveys and performance tests designed to evaluate the effectiveness of Excel in improving learning outcomes. Correlated paired t-test analysis of pre-test and post-test scores revealed that Excel significantly enhanced students' understanding of reinforcement design by simplifying complex calculations and allowing for real-time data analysis. The interactive nature of the tool improved engagement and reduced computational errors, exposing the need for some students to be availed of the required additional support in interpreting spreadsheet outputs. Integrating Excel into structural design education enhances learning by bridging the gap between theory and its application. Although challenges such as varying levels of Excel proficiency exist, this tool remains a valuable resource for fostering analytical thinking and preparing students for real-world engineering applications. Balanced instructional methods are recommended for achieving optimal learning outcomes.

Keywords: Excel-Based Tools, Rebar Computation, Simply Supported Slabs, Spreadsheet Outputs, Structural Design.

Introduction

Reinforced concrete design is the maxim of structural engineering; however, students often contend to comprehend its implementation. Traditional methods of instructing rebar computations are laborious and impede conceptual understanding (Kenward, et al., 2006). This study explored the potential of Microsoft Excel as an interactive tool to enhance structural design education, specifically focusing on rebar computation for simply supported slabs. Excel flexibility allows for the active control of variables, providing

immediate visual cues for design alterations (Charlesworth, 2025). This case study intends to demonstrate how incorporating Excel can transcend rote memorization to a robust comprehension of the design workflow, promoting logical and critical thinking competencies vital for future architects and structural engineers.

Learners in the Built Environment genre often struggle with the real-world use of reinforced concrete design frameworks, especially as it concerns rebar calculations. Traditional approaches relying heavily on manual computations can be labour-intensive and error-prone and may impede students' insight into the underlying notions (Daniel & Sunkuk, 2023). These methods frequently present rebar design as a series of isolated steps rather than a dynamic process influenced by multiple parameters. (Sergey, et al., 2023). This lack of conceptual grasp can limit students' ability to adapt design principles to different scenarios and to solve complex problems. Therefore, there is a need for a more efficient and engaging instructional method that fosters an in-depth comprehension of rebar calculations and promotes the evolution of essential analytical competencies in learners.

This study examined the efficiency of Microsoft Excel as a pedagogical high-end tool in the tutoring of rebar calculations for simply supported slabs. Its objectives include:

1. Develop an interactive Excel-based tool that accurately calculates rebar requirements for simply supported slabs based on established design principles.
2. Assess the impact of using this Excel tool on students' comprehension of rebar design concepts compared with traditional methods.
3. Examine whether the deployment of Excel enhances students' capability to analyze the impact of various design criteria (e.g., load, span, material properties) on rebar requirements; and
4. Offer data-driven recommendations for incorporating Excel into advanced construction curricula to improve the learning experience.

This study is significant for several reasons. First, it addresses the recognized challenge of effectively teaching reinforced concrete design, which is a critical skill for architects and structural engineers. By presenting the use of Excel for rebar calculations, it offers a functional, available, and interactive alternative to conventional, often tedious, manual computations (Cheusheva, 2025). This strategy can improve learners' understanding of design frameworks and inspire them to study the impact of diverse design alternatives.

Excel was selected for rebar computation in simply supported slabs owing to its accessibility, ease of use, and widespread adoption in engineering education (Seied & Majid, 2025). Unlike specialized software such as MATLAB or Revit, Excel requires minimal training, making it ideal for students and educators. Its flexibility allows custom formulas, iterative design modifications, and real-time visualization of the results. Furthermore, Excel supports automation through VBA, enhancing computational efficiency (Abdul, Muhammad, Muhammad, & Shakil, 2021). The affordability and compatibility with various devices further justify its selection. By integrating Excel into structural design education, students can develop essential analytical skills while leveraging a practical tool commonly used in professional engineering practice.

Integrating Excel in structural design education aligns with Constructivist Theory, fostering active learning through hands-on computation (Christi & Nai, 2016). Cognitive Load Theory supports its structured approach, reducing extraneous effort (Christa, Halszka, Femke, & Paul, 2025). Situated Learning Theory connects academic knowledge to industry practices (D & V, 2021), while Kolb's Experiential Learning Cycle enables iterative problem-solving, reinforcing conceptual understanding in structural engineering education (Alice & David, 2012).

Prior research on technology integration in structural design education has highlighted the benefits of computational tools in enhancing student learning, accuracy, and efficiency. Studies have emphasized the role of software such as MATLAB, Revit, and AutoCAD in automating calculations, visualizing structures, and improving conceptual understanding. However, research has also identified barriers, such as high costs, steep learning curves, and limited accessibility. Excel has been explored as an alternative owing to its intuitive interface, customizability, and widespread availability (Jacob, 2024). Studies suggest that integrating Excel in structural design courses improves problem-solving skills and practical applications, making it a viable tool for rebar computation in engineering education (Seied & Majid, 2025).

Recent studies have highlighted the growing role of digital tools in engineering education in improving engagement and computational efficiency. Research on Education 4.0 emphasizes technology-driven learning (Monica, Ali, Rick, & Heribert, 2017), while studies demonstrate Excel's effectiveness in structural design, enabling precise calculations and real-world applications. Such tools enhance problem-solving and bridge theoretical concepts with practical implementation.

Overall, this study can update educators about the benefits of incorporating spreadsheet applications into the curriculum, fostering the utilization of technology to enhance learning outcomes (Mulle, 2023). The results can be deployed to develop more proactive educational resources and pedagogical approaches, inevitably leading to better-equipped and more informed built environment alumni.

Literature Review

Structural design education plays a crucial role in preparing architects and civil engineers to produce secure and effective structural envelopes (Shirsath, 2024). It traditionally highlights conceptual understanding and manual computations, often zeroing in on basic frameworks, such as the strength of materials and load-bearing analysis. However, there is a lacuna between these conceptual frameworks and their practical implementation in actual design situations. Learners can find it difficult to picture the effects of various factors on load response and often contend with complicated, repetitive computations (J & Akanshu, 2011). This stresses the need for an ingenious teaching approach that closes this gap by promoting a deeper comprehension of design notions and enhancing students' proficiency in implementing these frameworks practically and realistically. The deployment

of high-end software, such as Microsoft Excel, can conceivably tackle these challenges by advancing an engaging and flexible learning environment (Ahmad & Muhammad, 2023).

Microsoft Excel is a powerful, yet accessible platform for enhancing learning in structural design. Its inherent spreadsheet functionality allows students to organize, manipulate, and analyze data efficiently, which is crucial for structural calculations. Unlike traditional methods, Excel facilitates the real-time exploration of design parameters; students can readily observe how changes in load, span, or material properties impact rebar requirements, fostering an intuitive understanding of design relationships (Mueller, 2006). Its visual nature, through charts and graphs, can also aid in the conceptualization of abstract structural concepts. Moreover, Excel's widespread availability and user-friendly interface make it a practical and versatile tool for both in-class learning and independent studies (Bala, 2024). This study posits that incorporating Excel into the teaching of rebar computation can shift learning from the passive assimilation of formulas to the active, interactive exploration of structural design principles.

Rebar calculation is a vital part of reinforced concrete design, as it guarantees the structural stability and reliability of concrete members (Reis, Bezerra, Azevedo, Christoforo, & Poggiali, 2023). This entails evaluating the size, spacing, and distribution of reinforcing steel bars required to counter tensile forces in concrete structures. This process is governed by building codes and structural design principles, considering factors such as applied loads, material properties, and member geometry. Traditional methods often rely on manual calculations based on simplified equations and charts. Although necessary, these methods can be repetitive and may not foster a deep conceptual understanding of the influence of different variables on rebar requirements. Furthermore, manual calculations are prone to error (Naresh & K, 2017). Hence, a more dynamic and interactive approach is needed to allow students to explore design parameters more effectively and gain a deeper understanding of the interplay between concrete and steel reinforcements.

Conceptual Framework

The incorporation of Excel in structural design learning is founded on widely recognized pedagogical theories that highlight hands-on, inquiry-based, and tech-assisted learning.

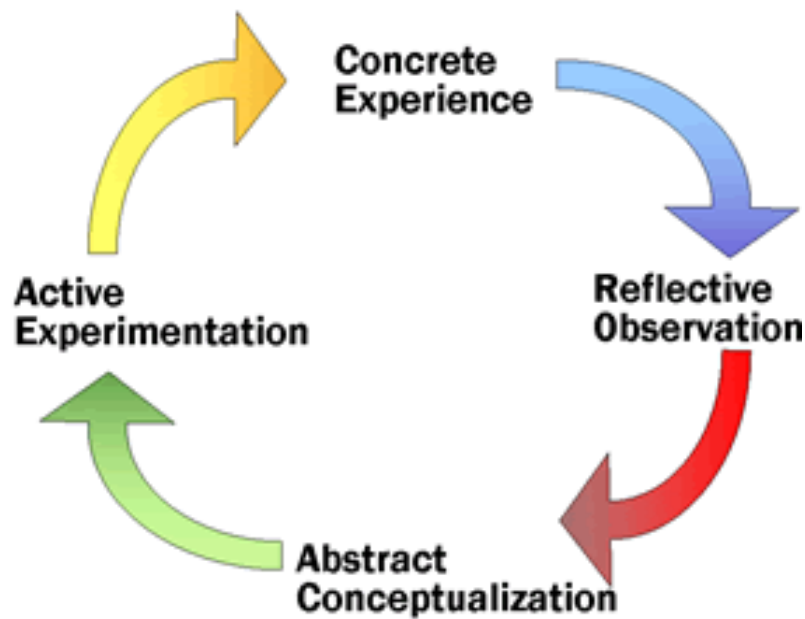


Figure 1: Karin Kirk's rendering of Alice and David Kolb's Experiential Learning Theory.
Source: SERC (2025).

This study is based on principles structured within the Experiential Learning Theory (ELT), Constructivist Learning Theory (CLT), and Technological Pedagogical Content Knowledge (TPACK) model. Such concepts offer a solid basis for deploying Excel as a learning tool to improve educational results in structural design.

a. Experiential Learning Theory (ELT)

Alice et al (2012) treatise ELT highlights learning as an iterative process of palpable experience, thoughtful analysis, high-order thinking, and practical engagement. In the structural design knowledge domain, Excel helps students dynamically engage with experiential challenges by performing practical rebar computations. Experiential learning starts by deploying Excel to compute reinforcement prerequisites, followed by critical reflection, where learners examine the effects of various parameters. Through abstract conceptualization, they connect algorithmic results to the pedagogical foundations of structural behaviour, and finally, they apply their comprehension to design enhancement in an active empirical study. This learning loop promotes critical thinking and a much more ingrained understanding of the fundamental concepts of reinforced design.

b. Constructivist Learning Theory (CLT)

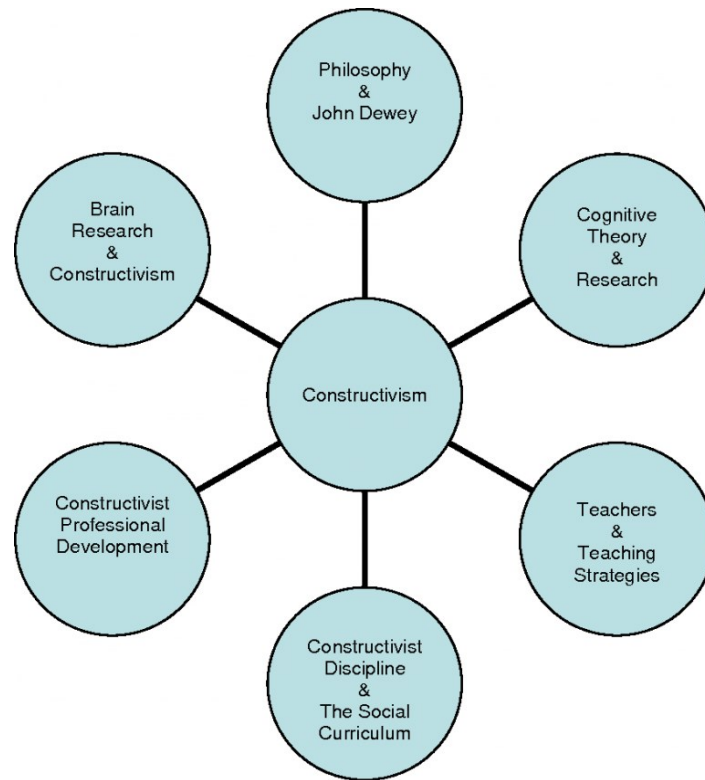


Figure 2: Rendition of Constructivist Learning Theory. **Source:** Kurt (2021).

Expounded by McLeod (2024), CLT asserts that knowledge is dynamically developed through investigation and cooperation. Excel functions as a support framework that enables students to engage with formulas, envision rebar layouts, and recalibrate design indices in real-time. This practical strategy improves problem-solving capabilities and self-directed learning. Additionally, social constructivism is included as learners partake in student-led discussions, compare results, and improve their comprehension through social constructivist learning (Amna, Huma, & Fara, 2021). This strategy reinforces personal knowledge and mirrors practical analytical engineering reasoning in professional practice.

c. Technological Pedagogical Content Knowledge (TPACK)

The TPACK structure incorporates innovation, instructional approaches, and domain expertise to improve learning (Matthew, Punya, Mete, & Joshua, 2013). As a technological high-end, Excel disassembles the gap between theoretical mathematical calculations and practical engineering implementation. Its engaging nature enables instructors to personalize learning experiences, offer instant responses, and encourage evidence-based decision-making. By inserting technology into instructional methods, students evolve computational expertise along with their structural design awareness, preparing them for skillset demands.

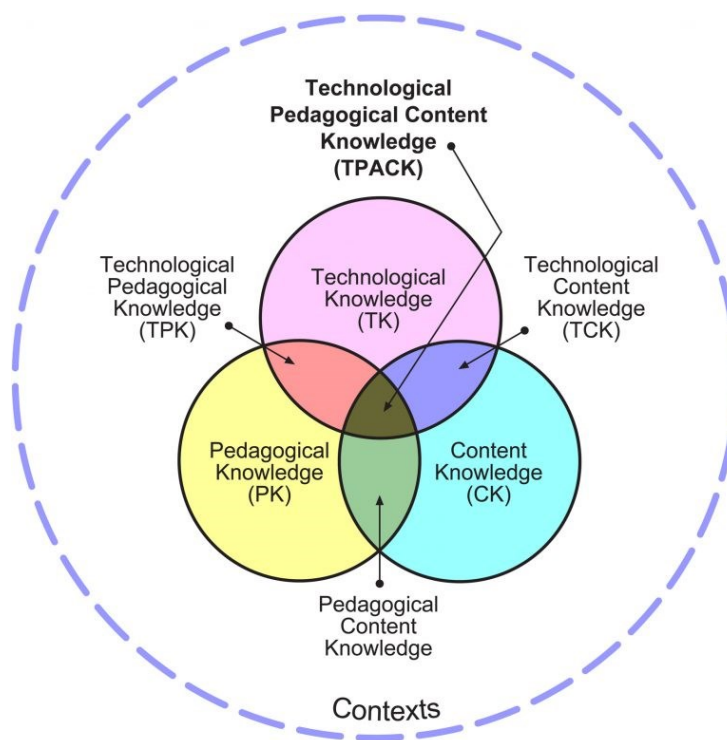


Figure 3: TPACK: Technological Pedagogical Content Knowledge Framework.

Source: Serhat (2018).

Methodology

Case Study Selection:

The beam and slab distribution layout at the +5100 mm levels of a client for a proposed block of flats was chosen as a case study because of its simplicity and suitability for illustrating core principles. Its relatively straightforward load path and clearly defined supports allow for a focused analysis of rebar calculations. The assumptions made include a uniformly distributed load, negligible self-weight (for simplified analysis), and elastic material behaviour. The parameters of the slab design encompass the span lengths of 1-way and 2-way spanning slabs, slab thickness, concrete compressive strength, concrete cover, drop-beam lengths, internal beam lengths, and assumed live load.

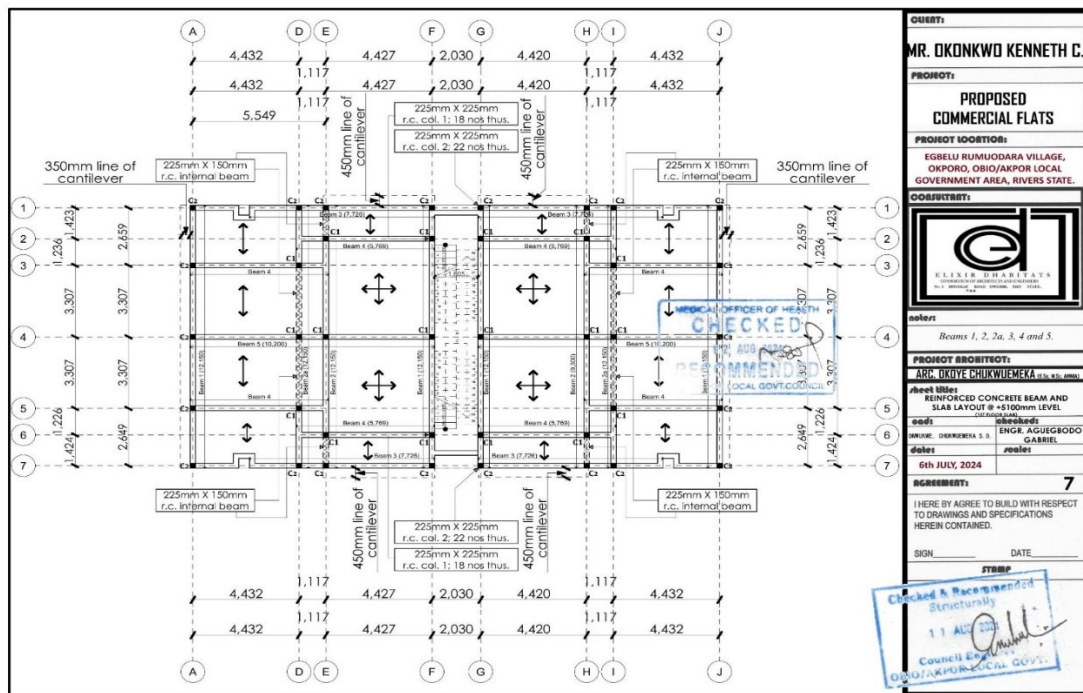


Figure 4: Stamped Beam and Slab Distribution Details at +5100 mm of a client billed for development in Rivers State, Nigeria.

These variables were intentionally kept within a realistic range to ensure relevance and encourage easier comparisons to real-world situations. The simplicity of the simply supported slab offers a clear demonstration of how Excel can support rebar calculations, serving as a veritable base for investigating more convoluted structural systems.

Development of the Excel Tool:

The spreadsheet is composed of three (3) parts. Each part represents the diameter of the High-yield Deformed Reinforcement Bar (HDRB): Y16, Y10 and Y12. All the bar codes have eleven (11) columns. It must be noted that each HDRB grows in rows. This growth was in response to the number of bar codes required for reinforcement. The parameters of columns 1-6 were inputted from the design. The parameters of columns 7 -11 were auto-generated.

A. Cells and Formulas of Columns

As shown in Figure 3, Columns 1-6 are manually inputted parameters from the structural slab design. These include (a). Column 1: Serial number (b). Column 2: Bar codes for each HDRB (c). Columns 3 and 4: Lengths of HDRBs for bottom and top rebars, (d). Column 5: Bay/span and (e). Column 6: HDRB Spacing. Columns 7-11 are auto-generated from the active spreadsheet. This includes (f). Column 7 (Distribution) = $QUOTIENT(E_4, F_4)$, (g1). Column 8 (Bar Lengths/B) = $PRODUCT(C_4, G_4)$, (g2). Column 9 (Bar Lengths/T) = $PRODUCT(C_4, G_4) = PRODUCT(D_4, G_4)$, (h). Column 10 (total bar length) = $SUM(H_4:I_4)$ and (i). Column 11 = $QUOTIENT(J_7, 12000)$.

G4										
=QUOTIENT(E4,F4)										
Y16										
s/n	Code	Length		Bay	Spacing	Distribution	Bar Lengths		Total Bar Length (mm)	Total Bar Lengths
		B	T				B	T		
1	Y1601	0	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
2	Y1602	0	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
3	Y1603	0	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
										#DIV/0!
Y10										
s/n	Code	Length		Bay	Spacing	Distribution	Bar Lengths		Total Bar Length (m)	Total Bar Lengths
		B	T				B	T		
1	Y1001	0	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
2	Y1002	0	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
3	Y1003	0	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
4	Y1004	0	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
5	Y1005	0	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
										#DIV/0!
Y12										
s/n	Code	Length		Bay	Spacing	Distribution	Bar Lengths		Total Bar Length (m)	Total Bar Lengths
		B	T				B	T		
1	Y1201	0	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
2	Y1202	0	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
3	Y1203	0	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
4	Y1204	0	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
5	Y1205	0	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
6	Y1206	0	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
7	Y1207	0	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
8	Y1208	0	0	0	0	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	
										#DIV/0!

HDRB
(Y16)

HDRB
(Y10)

HDRB
(Y12)

Figure 5: Spreadsheet design of rebar calculations required for reinforcement of simply supported slabs.

B. Simulating the spreadsheet

For demonstration purposes, the simulation involved a bar code for each HDRB. The excerpts of the slab systems, as shown in Figure 2, will guide the simulation.

(1). Y1601 (16mm) is the first bar code deployed on two slab systems (1-way and 2-way) and a 450mm cantilever projection as shown on grids 1-4 and grids E- F. The parameters of Y1601 are as follows: (a). Top (broken line/blue) = 2590 mm. (b). bottom (continuous line/blue) = 7393 mm. (c). Bay = 4651mm. (d). Spacing = 150mm. See Figure 4.

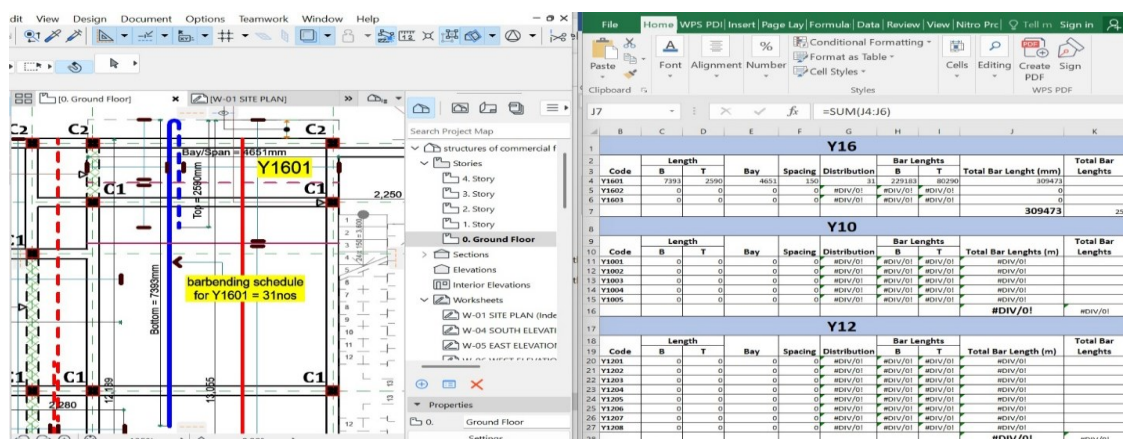


Figure 6: Computation of Y1601 for 1-way slab system, 2-way slab system and 450 mm cantilever as shown in Grids 1-4 and Grids E-F.

The treated slab systems and proximal cantilever require 25 lengths of Y16. The same is applicable for the additional bar codes in Y16 HDBR.

(2). Y1001 and Y1002 (10mm) are the first and second bar codes of the Y10 HDRB. Y1001 is located at the top side and perpendicular to the top of Y1601. The parameters of Y1001 are as follows: (a). Top (broken line/purple) = 4651 mm. (b). bottom = -nil-. (c). Bay = 2590mm. (d). Spacing = 300mm. Y1002 was located at the bottom and perpendicular to the bottom of Y1601. The parameters of Y1002 are as follows: (a). top = -nil-. (b). bottom = (continuous line/purple) = 4651 mm. (c). Bay = 7393mm. (d). Spacing = 300mm. See Figure 5.

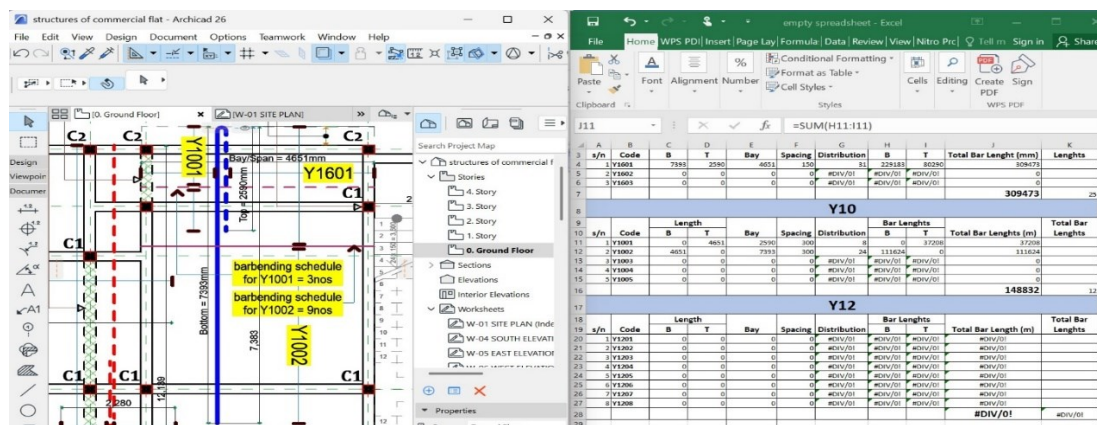


Figure 7: Computation of Y₁₀₀₁ and Y₁₀₀₂ for 1-way slab system, 2-way slab system, and 450 mm cantilever, as shown in Grids 1-4 and Grids E-F.

The treated slab systems and proximal cantilever required a total of 12 Y10 lengths. The same is applicable for additional bar codes in the Y10 HDBR.

(3). Y1201 and Y1202 (12mm) are the first and second bar codes deployed on four slab systems (1-way slab systems) as shown on grids 1-7 and grids A.

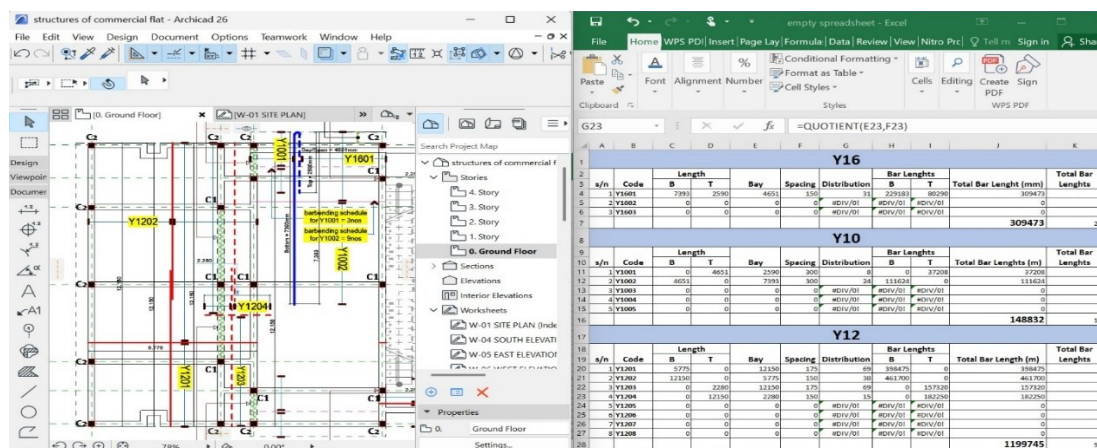


Figure 8: Computation of Y1201, Y1202, Y1203, and Y1204 for 1-way slab systems, as shown on Grids 1-7, Grids A-E, and Grids D-E.

The parameters of Y1201 are as follows: (a). top = -nil-. (b). bottom (continuous line/red) = 5775 mm, (c). Bay/Span = 12150mm. (d). Spacing = 175mm. The parameters of Y1202 are as follows: (a). top = -nil-. (b). bottom (continuous line/red) = 12150 mm, (c). Bay/Span = 5775mm. (d). Spacing = 150mm.

Y1203 and Y1204 (12 mm) are the third and fourth bar codes deployed on four slab systems (1-way slab systems), as shown in grids 1-7 and grids D- E. The parameters of Y1203 are as follows: (a). Top = (broken line/red). (b). -nil-. (c). Bay/Span = 12150mm. (d). Spacing = 175mm. The parameters of Y1204 are as follows: (a). Top = (broken line/red). (b). bottom = -nil-. (c). Bay/Span = 2280mm. (d). Spacing = 150mm.

The treated slab systems required 99 lengths of Y12. The same is applicable for the additional bar codes in Y12 HDBR.

Sampling Methods, Student Selection Criteria and Statistical Validation:

This study deployed a stratified random sampling method to guarantee unbiased representation across various skill levels in structural design education. Students were categorized based on their previous exposure to reinforced concrete design and algorithmic tools, ensuring an equitable mix of experience levels. Furthermore, purposive sampling was used to include students actively involved in advanced building construction coursework, ensuring that the participants had the necessary basic knowledge for rebar calculations.

For statistical validation, paired t-test analysis was conducted to examine the effectiveness of Excel-based learning for rebar computations in simply supported slabs. The test compared students' performance before and after Excel integration, establishing whether there was a statistically significant optimization in computational accuracy and efficiency in rebar calculations. Students who participated in the pre-tests were considered the control group. The post-test cohort comprised students who had been exposed to an Excel spreadsheet template. Descriptive statistics were used to synthesize performance trends, and Cronbach's alpha was used to assess the reliability of students' responses.

By merging structured sampling methods with rigorous statistical analysis, this study provides a comprehensive evaluation of Excel's role in improving structural design education. The viability of the findings will advise curriculum reviews towards the integration of digital tools targeted to enhance students' computational skills and overall grasp of fundamental reinforced concrete design principles.

Data Collection and Evaluation:

Data collection for this study employed a mixed-methods approach to comprehensively evaluate the impact of Excel. Quantitative data were gathered through *pre- and post-tests* measuring changes in students' knowledge and skills related to rebar computation, with scores from a traditionally taught group serving as a comparison. Qualitative data collection involved *5-point, structured Likert-scale surveys* to assess student perceptions of tool usability, learning experience, overall feedback on the Excel tool, *instructor observations* focusing on student engagement, conceptual understanding of structural indices, use of the

Excel tool, pace and flow of learning sessions, and general classroom climate. The assessment commenced with a statistical analysis of performance scores, followed by a thematic evaluation of Likert-scale answers and a diagnosis of instructor notes. The outcomes were then cross-verified by comparing the conclusions across all datasets to acknowledge alignments and deviations. This process guaranteed a robust comprehension of Excel's efficiency, focusing on its capabilities, drawbacks, and prospects for improving structural design education. Ethical considerations and limitations of the study were also considered. This comprehensive analysis provided rich insights into the impact of the tool from multiple perspectives and contributed to a detailed evaluation of its effectiveness.

Ethical Considerations:

The ethical considerations in using Excel for structural design education include ensuring accuracy, academic integrity, and the responsible use of technology. Errors in rebar computation can lead to unsafe designs, emphasizing the need for validation and peer review. Transparency in data handling, formula accuracy, and adherence to engineering standards is essential. In addition, students must be taught to critically assess software-generated results rather than relying blindly on automated outputs. Ethical teaching also involves inclusivity, ensuring that all students have access to Excel and the necessary resources. Intellectual property concerns arise when sharing custom spreadsheets, which require proper attribution and respect for proprietary content.

Results and Discussions

Pre-and-post Tests: Table 1 shows the pre-and post-tests of traditional and Excel-enhanced pedagogies of rebar computations conducted across three academic sessions for a group of HND II students in Advanced Building Construction. Due to space restrictions, seven data strings were shown in all three academic sessions.

Table 1: Performance assessment scores of students exposed to traditional and Excel-enhanced pedagogies in rebar calculations across three academic sessions.

2021-2022 ACADEMIC SESSION				2022-2023 ACADEMIC SESSION				2023-2024 ACADEMIC SESSION			
Test scores of 60 students				Test scores of 60 students				Test scores of 60 students			
Stud ents' ID	Pre-test (Conven tional)	Post- test (Exc el- assis ted)	Differ ence (Post- Pre)	Stud ents' ID	Pre-test (Conven tional)	Post- test (Exc el- assis ted)	Differ ence (Post- Pre)	Stud ents' ID	Pre-test (Conven tional)	Post- test (Exc el- assis ted)	Differ ence (Post- Pre)
1.	65	85	20	1.	65	80	18	1.	65	85	22
2.	70	88	18	2.	74	90	16	2.	75	89	14
3.	72	90	18	3.	68	84	16	3.	71	90	19
4.	68	84	16	4.	55	70	15	4.	68	84	16
58.	63	77	14	58.	64	79	15	58.	62	79	17
59.	65	79	14	59.	60	74	14	59.	65	82	17
60.	74	90	16	60.	78	94	16	60.	66	83	17

Note: Authors' assessment sheets, November 2024.

2021-2022 ACADEMIC SESSION - t-Test: Paired Two Sample for Means		
	65	85
Mean	69.61016949	85.35593
Variance	40.3798948	39.50906
Observations	59	59
Pearson Correlation	0.969155539	
Hypothesized Mean Difference	0	
df	58	
t Stat	76.97554247	
P(T<=t) one-tail	2.12636E-60	
t Critical one-tail	1.671552762	
P(T<=t) two-tail	4.25272E-60	
t Critical two-tail	2.001717484	

2022-2023 ACADEMIC SESSION - t-Test: Paired Two Sample for Means		
	62	80
Mean	68.40678	84.13559
Variance	41.5903	46.73992
Observations	59	59
Pearson Correlation	0.990821	
Hypothesized Mean Difference	0	
df	58	
t Stat	-123.328	
P(T<=t) one-tail	3.37E-72	
t Critical one-tail	1.671553	
P(T<=t) two-tail	6.75E-72	
t Critical two-tail	2.001717	

2023-2024 ACADEMIC SESSION - t-Test: Paired Two Sample for Means		
	63	85
Mean	68.76271	85.74576
Variance	30.45996	29.05494
Observations	59	59
Pearson Correlation	0.973334	
Hypothesized Mean Difference	0	
df	58	
t Stat	-103.028	
P(T<=t) one-tail	1.09E-67	
t Critical one-tail	1.671553	
P(T<=t) two-tail	2.18E-67	
t Critical two-tail	2.001717	

Figure 9: Paired-t-test analysis of pre-test and post-test sessions involving 60 students each in three sessions.

Based on the paired t-test analysis of all three scenarios, $P(T \leq t)$ one-tail was less than 0.05. Therefore, the difference is significant in one direction. $P(T \leq t)$ two-tailed was < 0.05 . Therefore, the overall difference is statistically significant. In all cases, the p-values were less than α . Therefore, the null hypothesis – “*The Excel-based approach has no impact on learning outcomes compared to the existing method,*” is rejected. This indicated a statistically significant difference between the means of the two groups. This helps ensure the closure of the 2nd objective.

Structured Surveys:

A five-point structured Likert survey was administered to elicit responses from participants based on (a). Usability of Excel (b). Learning experience using Excel (c). overall feedback on the Excel tool and (d). Individualized inferences that could influence responses.

Table 2: 5-point Structured Likert Survey administered to elicit responses

SECTION	QUESTIONS	RESPONSES				
		Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Section 1: Usability of the Excel Tool	1. The Excel tool was easy to navigate and use.					
	2. The instructions for using the Excel tool were clear.					
	3. The input fields in the Excel tool were well-organized.					
	4. The output calculations were easy to understand.					
Section 2: Learning Experience with the Excel Tool	5. Using the Excel tool helped me understand how different parameters (span, load, etc.) affect rebar requirements.					
	6. The Excel tool made the connection between structural theory and practical application clearer.					
	7. Using the Excel tool was a more engaging learning experience compared to traditional calculation methods.					
	8. The tool helped me better understand the principles of load distribution in a simply supported slab.					
	9. The tool allowed me to experiment with different design scenarios effectively.					
	10. I felt more confident in performing rebar calculations after using the Excel tool.					
	11. The interactive features of the Excel tool were useful for my learning.					
Section 3: Overall Feedback on the Tool	12. I would recommend using the Excel tool in future structural design courses.					
	13. The time I spent learning with the Excel tool was well-utilized.					
	14. The Excel tool was a valuable resource for learning rebar computation.					
	15. I found the Excel tool helpful for visualizing structural concepts					
	16. Overall, I found the Excel tool to be helpful in my learning.					
Section 4: Remarks						

Note: Authors’ assessment sheets, November 2024.

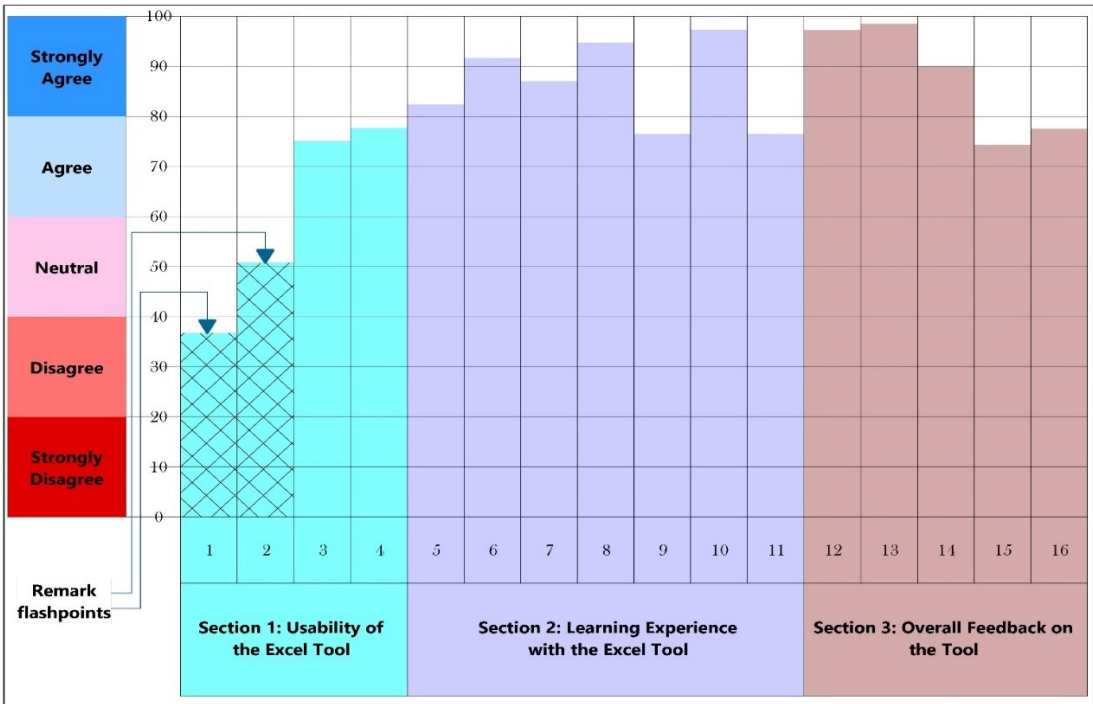


Figure 10: Visualization of the response pattern of participants in the study

As can be observed, participants’ responses to the usability of the Excel tool were moderate, with 50% of the responses below ‘agreement’. Responses to learning experiences with the Excel tool and overall feedback on the tool were high in ‘agreement.’ This helps to ensure

the closure of the 3rd objective. Most of the remarks hovered around the first and second variables of Section 1.

Observations:

The table below encapsulates the observations made, collated, and assessed by the authors during different rebar computation instruction sessions.

Table 3: Polled observations and assessments.

S/N	Area of Observation	Subsets	Observations	Scaled Assessment of Observations 1= low; 10 = high									
				1	2	3	4	5	6	7	8	9	10
1	Student Engagement	Active Participation	Rating of engagement in asking questions and discussing ideas.										
		On-Task Behaviour	Concentrate on independent work and focus on using the tool.										
		Enthusiasm/Motivation	Motivation, enthusiasm and curiosity to explore different scenarios.										
2	Understanding of Concepts	Question Types	Questions focused on the mechanics of using the tool.										
			Questions focused on underlying structural concepts.										
		Conceptual Errors	Propensity of common conceptual errors.										
			Rate of identification and correction with the tool.										
		"Aha" Moments	Students experience moments of insight or understanding as they use the tool.										
3	Use of the Excel Tool	Navigational Fluency:	Students can navigate and use the Excel tool after instruction.										
			They are comfortable with the input and output sections of the spreadsheet.										
		Parameter Manipulation	Students just plug in numbers out of curiosity.										
			Students intentionally experiment with different parameters and reflect on the results.										
4	Pace and Flow of Activity	Troubleshooting	Students can identify and correct their mistakes effectively.										
		Time Management	Students need more time than allocated.										
			Students are completing exercises efficiently.										
		Areas of Difficulty	Specific sections of challenges.										
			Varied sections of challenges										
5	General Classroom Climate	Flow	Suitable overall pace and flow of the activity.										
			Students are engaged and challenged.										
		Engagement and Participation	Students are participating and working together.										
		Frustration Levels	Students express signs of frustration and give up easily.										
		Overall Mood	Sense of curiosity and learning.										

Note: Authors' assessment sheets, December 2024.

Instructors observed that integrating Excel into Advanced Building Construction education significantly enhanced student engagement and conceptual understanding of structural indices. The interactive nature of the Excel-based rebar computation tool allowed students to visualize calculations fluidly, reinforcing their grasp of the reinforcement design principles. Many students exhibited increased confidence in applying formulas and

analyzing structural behaviour, encouraging a more analytical approach to problem-solving.

The pace and flow of the learning session improved as students quickly adapted to the tool, reducing reliance on manual computations and enabling more time for discussion and critical thinking. However, some students had issues mastering the spacing between the main and distribution rebars. The overall classroom climate was positive, with collaborative learning being encouraged through peer discussions and troubleshooting exercises. The use of Excel streamlined the learning process, making structural computations more accessible while bridging the gap between theoretical knowledge and practical applications.

Potential Biases and Limitations:

Potential biases and limitations of using Excel for structural design education include over-reliance on automated computations, which may reduce critical thinking in manual design processes. The accuracy of Excel depends on user input, making errors in formulas or data entries a significant risk. The software's lack of built-in structural analysis functions limits its applicability compared with specialized engineering tools. Additionally, students unfamiliar with Excel may face a steep learning curve, creating disparities in their skill levels. The focus on Excel may also exclude exposure to more advanced computational tools, such as MATLAB or structural analysis software, potentially limiting broader technological competency.

Discussions

The findings suggest that integrating Excel into structural design education significantly enhances student engagement, computational efficiency, and conceptual understanding. The interactive nature of Excel allows students to visualize reinforcement calculations, apply structural formulas dynamically, and analyze results with greater clarity (Louis & Elyssa, 2019). This approach fosters a more analytical mindset, enabling students to link theoretical knowledge with practical applications. Many students demonstrated increased confidence in structural computations, though some required additional support in interpreting the spacing and distribution parameters of different bar codes.

The implications for structural design education are profound. By automating complex calculations, Excel reduces manual workload, allowing more time for discussions, critical thinking, and design exploration. This shift better prepares students for practical engineering applications where computational tools are essential. Moreover, Excel promotes an interactive and collaborative learning environment, making structural computations more accessible and engaging (Nchimunya & Langstone, 2016).

Comparing the findings of this study with prior research highlights key advancements in structural design education. Previous studies have emphasized the importance of digital tools in engineering education but often focus on complex software rather than Excel's accessibility. This study confirms that Excel enhances learning efficiency and accuracy in

rebar computation for simply supported slabs, aligning with findings on interactive and practical learning methods. Unlike prior research that primarily evaluates professional design tools, this study demonstrates Excel's effectiveness in bridging theoretical knowledge and practical application. These comparisons reinforce the conclusion that Excel is a viable and accessible tool for structural design education.

Conclusion and Recommendations

This study confirms the effectiveness of Excel as a high-end tool for improving structural design education, especially in rebar calculation for simply supported slabs. The results substantiate that Excel enhances students' comprehension of reinforcement computations by offering an engaging, intuitive, and efficient platform for algorithmic calculation. Juxtaposed with complicated structural design software, Excel provides increased usability while maintaining computational precision. Moreso, the study emphasizes that incorporating Excel into coursework improves students' critical thinking abilities while promoting a stronger understanding of structural principles. These outcomes align with prior studies supporting digital tools in engineering education, towards reinforcing the potential of Excel as an instructional resource.

In light of the findings, it is recommended that structural design curricula embed Excel-based algorithmic drills to complement conceptual understanding. Educators should develop structured modules that guide students through the step-by-step process of rebar computation using Excel. Further research should explore the long-term impact of Excel-based learning on students' design proficiency and compare its effectiveness with other digital tools. Additionally, integrating automated Excel templates with visual outputs could enhance learning outcomes. Industry professionals should also consider Excel for preliminary design assessments, leveraging its versatility for quick and efficient reinforcement calculations.

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