Utilizing CSi API Embedded in VBA for Designing Reinforced Concrete Beams According to TCVN 5574:2018

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ABSTRACT

This paper presents an approach to designing reinforced concrete (RC) beams in accordance with TCVN 5574:2018 using the CSi Application Programming Interface (API) integrated with VBA Excel. By connecting directly to ETABS, the method automatically extracts critical internal forces, including negative moments at the 1/4-span, positive moments at the 1/5-span, and shear at three selected sections according to a simplified formula. It further identifies the location of shear force Q near the support if a <2.5h$_o$*. Comparison with conventional design methods reveals that automating data retrieval through CSi API substantially reduces the manual effort required and mitigates potential errors in entering internal forces. In addition, key results-such as negative and positive moment values-are systematically filtered and organized, allowing engineers to quickly evaluate flexural and shear demands on the beam. Overall, the study underscores the benefits of leveraging CSi API in conjunction with VBA Excel for efficient, accurate, and reliable RC beam design.*

Keywords*: API, Etabs, VBA, TCVN 5574:2018, Reinforced Concrete beam, Moment, Shear force.*

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1. INTRODUCTION

Modern structural engineering projects demand efficient and error-minimized design workflows. In practice, however, many structural designers still perform critical design calculations manually or using stand-alone spreadsheets, even after conducting analysis in advanced software. In VietNam, it is common to use ETABS for structural analysis but then export results by hand into Excel to check reinforced concrete (RC) member capacities - a cumbersome and time-consuming process that is prone to transcription errors and inconsistent interpretation of code provisions . Such manual workflows not only slow down the design cycle but also divert engineers' effort to repetitive tasks rather than creative or critical thinking. Automation offers a compelling solution: by automating the transfer of analysis results and execution of design checks, engineers can eliminate slow, tedious, and repetitive operations from the workflow. Prior studies [1-5] have demonstrated that embedding design logic into spreadsheets or scripts can carry out procedures that would be impractical to perform repeatedly by hand, thereby improving both productivity and accuracy. This motivation underpins the push to integrate the structure software and Visual Basic for Applications (VBA) - Macro into structural design - freeing engineers from clerical computations and reducing the likelihood of human error in applying complex design formulas.

The drive toward automation is part of a broader digital transformation occurring in civil engineering and construction. The Architecture, Engineering, and Construction (AEC) industry has historically lagged in digital adoption, with the engineering and construction sector ranked among the world's least digitized industries. Consequences of this lag are evident in persistent inefficiencies: over-reliance on outdated manual processes has been cited as a root cause of project delays and errors in construction workflows [6]

In recent years, however, momentum has shifted as firms recognize the substantial gains possible through digital tools. McKinsey's research indicates that successful implementation of digital technologies in AEC can raise productivity by roughly 14-15% and cut costs by 4-6% on projects [7]. In fact, industry analyses suggest that globally the construction sector could unlock on the order of $1.6 trillion of additional value per year by embracing automation, data integration, and advanced software solutions [8]. These statistics underscore a clear imperative: to remain competitive and meet modern infrastructure demands, civil engineering must leverage computational tools at every stage from planning to detailed design. Nationally in Vietnam, this imperative is reinforced by government initiatives and industry partnerships aiming to modernize practice through Building Information Modeling (BIM) and design software integration. Within this context, automating structural design tasks – such as RC beam design – is both a reflection of the global digital transformation trend and a practical step to improve engineering outcomes in the local construction industry.

Designing reinforced concrete (RC) beams is a fundamental task in structural engineering and is governed by strict code requirements to ensure safety and performance. In Vietnam, the relevant standard is TCVN 5574:2018 [9], which is the current national code for concrete and reinforced concrete structures. This standard took effect in late 2018, replacing the previous TCVN 5574:2012 [10] and marking a significant modernization of design guidelines. The older code was essentially a carryover of a 1984 Soviet-era standard which is currently SP 63.1330.2012 [11], meaning Vietnamese practice was lagging behind contemporary engineering advances. Such outdated provisions led to various inadequacies in design practice. In current practice, there is a noticeable lack of integrated software solutions catering to TCVN 5574:2018 for detailed member design. Engineers often perform structural analysis using general-purpose finite element programs, then export results to spreadsheets for manual code compliance checks. This fragmented workflow is time-consuming and prone to errors, undermining the potential benefits of the new code. Mainstream structural software may not natively implement newest Vietnamese standards of TCVN 5574:2018, forcing practitioners to devise their own checks. Indeed, existing design software frequently fails to meet specific local needs or provide seamless integration between analysis and design phases. The result is a gap between analysis output and design verification, which digital transformation efforts have yet to fully close in the Vietnamese context.

To address the above challenge, this research leverages the open Application Programming Interface (API) of CSI's ETABS software, embedding it within a Visual Basic for Applications (VBA) environment (e.g. an Excel workbook). ETABS's API provides programmatic access to the software's analysis engine and data, allowing external programs to extract results, perform calculations, and even create or modify models. The API supports multiple programming languages – including VBA, which is readily accessible to engineers through Microsoft Excel. Because Excel VBA is used for automation and is a familiar tool. Many structural engineers already use Excel spreadsheets for design calculations. So, embedding ETABS API calls in Excel is an effective extension of current practice [12-15]. According to CSI documentation, engineers can employ the Application Programming Interface (API) from within a spreadsheet to run analyses and retrieve results back into Excel for further processing. This capability enables a seamless integration: once an ETABS analysis is completed, the VBA macros can automatically fetch internal forces and other analysis outputs for each beam, then compute the required reinforcement and check compliance with TCVN 5574:2018's formulas and criteria. The benefits of such integration are substantial. First, it eliminates the manual transcription of analysis results, which was identified as a major bottleneck in traditional workflows . Instead of manually copying forces or moments into a separate calculation sheet (with potential for mistakes), the API ensures data flows directly and accurately. Second, the design checks can be carried out swiftly and consistently for all beams in the structure, enforcing the code's provisions uniformly and flagging any non-compliance immediately. This improves both speed and quality, as the engineer can iterate on the design (adjusting member sizes or reinforcement) with instant feedback from the automated checks. The result is a more efficient design process that saves time, reduces errors, and helps Vietnamese RC design practices stay aligned with VietNam standards and technology.

2. METHODOLOGY

This study adopts a computational approach to develop an automated workflow for the design of reinforced concrete beams in accordance with TCVN 5574:2018, utilizing the CSi API integrated with VBA (Visual Basic for Applications) in Microsoft Excel. As shown in Figure 1, the methodology is structured into five key stages.

Figure 1. Implementation process

First, a comprehensive review of the theoretical background and design principles specified in TCVN 5574:2018 is conducted, focusing on flexural, shear, and axial strength requirements, as well as detailing rules for reinforcement arrangement. Simultaneously, the capabilities of the CSi API are analyzed to understand its object-oriented structure, data extraction methods, and integration potential with VBA.

Second, the manual design process is formalized into an automated computational workflow, defining the sequential tasks required to input data, retrieve internal forces from CSi models, perform reinforcement calculations, and export results to Excel. Third, the VBA programming environment is established, and functional modules are developed to connect to CSi software (ETABS or SAP2000), extract design parameters, execute structural calculations based on Vietnamese standards, and generate formatted output.

Fourth, the automated tool is validated through multiple case studies involving different beam configurations, loads, and material properties. Results obtained from the automated calculations are cross-verified with manual computations to ensure accuracy and reliability. The efficiency and flexibility of the tool are also assessed in terms of design productivity and adaptability to various project requirements.

Finally, practical recommendations are proposed for the implementation of the developed workflow in design offices, highlighting its potential for expansion to other structural elements such as columns, slabs, and foundations. The methodology provides a systematic framework for advancing digitalization in structural design practice, particularly in the context of applying national standards through automated computational tools.

2.1. Connecting VBA Excel with the CSi API

The CSi API is integrated through Excel's VBA environment to facilitate automated data exchange with ETABS. The API provides programmatic access to ETABS, allowing internal forces (such as bending moments and shear forces) to be directly retrieved from the analysis model into Excel. In this implementation, the ETABS API is invoked via COM interface: a VBA macro creates or attaches to an ETABS object and obtains a handle to the model (often via GetObject to connect to a running ETABS instance). This connection enables Excel to pull analysis results without manual intervention. The VBA code is organized into structured modules and macros to separate concerns. For instance, one module is dedicated to establishing the ETABS connection and retrieving data, while another handles the design calculations. This approach makes the connection between Excel and ETABS more direct in terms of data transfer. Key steps in the integration process are as follows: Initialize ETABS Interface, Retrieve Internal Forces, Data Transfer to Excel and Write to from VBA Excel to access the Etabs commands.

Initialize ETABS Interface: An ETABS OAPI object is created or attached using VBA (e.g., using GetObject(, "CSI.ETABS.API.ETABSObject")). This gives access to the ETABS application and its SapModel, which represents the current structural model.

Retrieve Internal Forces: The macro invokes ETABS API methods to read internal force results. All relevant beam elements are identified, and their bending moments and shear forces are extracted for specified load cases or combinations. For example, calls like SapModel.Results.FrameForce can be used to obtain moment (M) and shear (V) values at critical points along each beam. The API returns these values which are then stored into Excel (in arrays or worksheet cells).

Write Commands to ETABS: In addition to reading data, the API allows writing data or commands to ETABS. The Excel macro could send instructions to run the analysis or update load combinations. In this workflow, ETABS is mostly the data source while Excel is the calculation platform, so writing to ETABS is limited to tasks like initiating analyses or reading updated results as needed.

Data Transfer to Excel: The retrieved forces are automatically populated into the Excel workbook. This may involve writing values into a results sheet or storing them in VBA variables for immediate use. The data typically includes maximum positive/negative moments and shear forces for each beam from the governing load combinations.

Through this read/write mechanism, Excel and ETABS remain synchronized. The Excel VBA macros act as a controller: instructing ETABS to provide the needed information (internal forces) and then proceeding with design computations in Excel. The integration is seamless – changes in the ETABS model can be reflected by re-running the macro to fetch new forces, and design outputs can be quickly updated. This approach eliminates manual data entry, reduces errors, and accelerates the design workflow by leveraging ETABS's analysis capabilities in tandem with Excel's computational flexibility

2.2. Key Advantages of Embedding the CSi API in Excel VBA

Compared to the traditional method, where Excel VBA connects to ETABS through an intermediate Access database file, CSi API enables direct interaction between ETABS and Excel without requiring export and import steps. In the older approach, ETABS results must be saved as an Access file, then imported into Excel, which not only complicates the workflow but also prolongs the design revision process. By contrast, using the CSi API allows Excel to communicate directly with ETABS, issuing commands to select and retrieve results for beam or frame elements immediately in the worksheet. This direct link significantly reduces the manual effort and time required for data updates. Specifically, the code Cm1 is used to connect with the selected beam element.

SapModel.SelectObj.GetSelected	Cm1

ETABS model data can be readily transferred into Excel spreadsheets through

CSi API commands, including the retrieval of load combinations, beam element properties, label of element and internal forces. Specifically, some of the commands from Cm2 to Cm6 are introduced, with Cm2 is used to get load combinations, Cm3 to retrieve beam element properties, Cm4 to obtain the output internal forces, Cm5 to get the label of the element, and Cm6 to determine the length of the elements.

SapModel.RespCombo.GetNameList	Cm2
SapModel.PropFrame.GetRectangle	Cm3
SapModel.Results.FrameForce	Cm4
SapModel.FrameObj. etLabelFromName	Cm5
SapModel.PropFrame.GetNonPrismatic	Cm6

Additionally, certain API commands enable modifications to beam element properties, such as specifying the number of output stations or running analysis model, directly from within the Excel environment. Specifically, Cm7 is used to assign the number of output stations, and Cm8 is used to run the model.

SapModel.FrameObj.SetOutputStations	Cm7
SapModel.Analyze.RunAnalysis	Cm8

As shown in Figure 2, a common challenge that consumes significant engineering time involves separating the negative moment at the supports (cross-section 1-1 and 7-7) and at the quarter-span (L/4) (cross-section 3-3 and 5-5), where tension longitudinal bars are potentially be reduced. Another related issue is determining the reduced area of supplemental bars for the positive moment region, which typically occurs at about 1/5 of the beam's length from the support (Cross-section 2-2 and 6-6), where L is the length of the beam. In practical design workflows, many engineers only design longitudinal bars for three cross sections at cross-section of 1-1, 4-4 and 7-7, then apply empirical formulas to reduce the amount of longitudinal bars for the following zones

- For the nagetive moment, the bars may be reduced for the beam segment extending from cross section 3-3 to 5-5 along the beam's length, Henceforth, this region is referred to as the negative moment steel reduction zone.
- For the positive moment, the bars may be reduced for the beam segment extending from the left support to cross section 2-2 and form 6-6 to right support. Henceforth, this region is referred to as the positive moment steel reduction zone.

This approach can be inadequate because the main reinforcement may prove insufficient to resist the negative moment at the mid-span, or the positive moment in the positive moment steel reduction zone.

These issues can be quickly resolved by automatically retrieving internal forces at the support and quarter-span sections for negative moments, as well as at mid-span and the 1/5-span section for positive moments. This is accomplished via automated moment extraction from ETABS using API commands, where the number of output stations is set to 21, ensuring sufficiently detailed data for each location of interest.

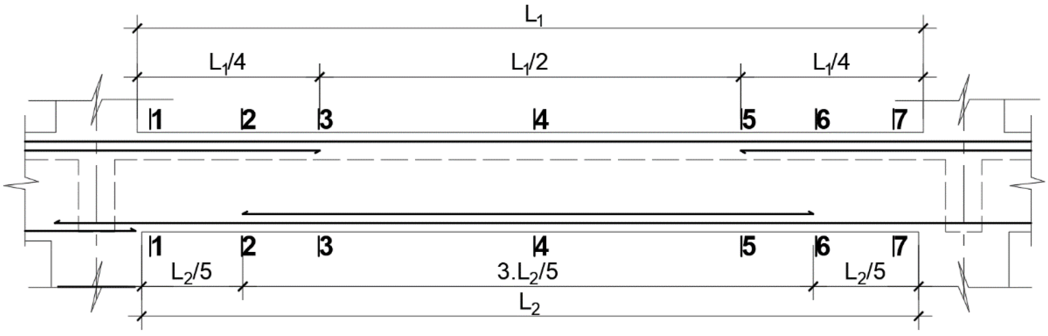


Figure 2. Output internal moments for flexure resistance design

Calculations for shear capacity are performed at three positions where shear typically peaks: the left quarter-span, the mid-span which is a haft-beam length, and the right quarter-span. However, for both quarter-span segments, TCVN 5574 uses a simple formula that requires checking the distance 'a' from the support to the shear force, considering whether it is greater than or less than 2.5 times the height of the cross-section (ho). Manual or basic VBA Excel procedures often struggle to pinpoint this specific location of the maximum shear. By contrast, integrating the "*output station*" setting and retrieving the *beam's length via the API* simplifies identifying the ratio of a to 2.5h_o. Consequently, the correct shear calculation formula from TCVN 5574:2018 can be automatically applied, improving both accuracy and efficiency in design, as shown in Figure 3.

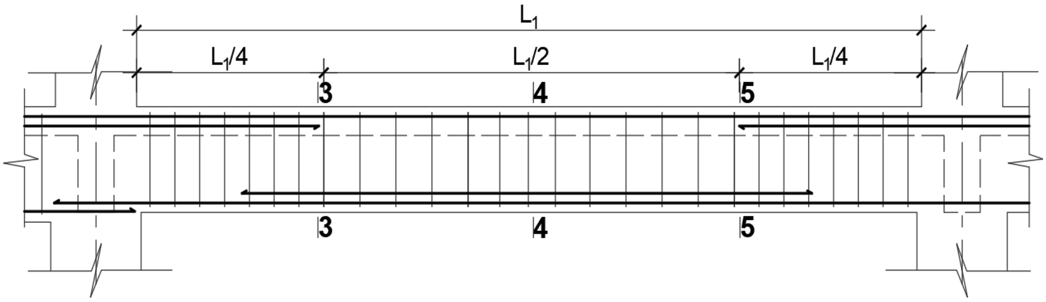


Figure 3. Output internal Shear for flexure resistance design

2.3. Reinforcement Design Algorithm According to TCVN 5574:2018

- **Flexural Strength Resistance**:

The sectional analysis method is widely regarded as a fundamental tool for designing and assessing the load-carrying capacity of reinforced concrete (RC) structural members. Its core principle involves evaluating the stress–strain state at a specific cross section by considering the distribution of stress in both concrete and steel under applied loads. Through this approach, it becomes possible to accurately estimate the member's strength, durability, and overall stability in accordance with applicable design standards.

In practice, the sectional analysis method typically applies several key assumptions, including Bernoulli's hypothesis (plane sections remain plane), nonlinear material modeling for both concrete and steel, and internal force equilibrium at the cross section. The analysis process generally consists of constructing stress–strain diagrams and verifying the section's safety under various loading scenarios or limit states.

Owing to its capacity to yield reliable results for internal forces, load-bearing capacity, and structural performance, the sectional analysis method has become a preferred choice in the design of beams, columns, slabs, and walls. It is implemented extensively in standards such as TCVN 5574:2018, ACI 318-19 [16], and Eurocode 2 [17], reflecting its effectiveness and broad applicability in modern RC design practice.

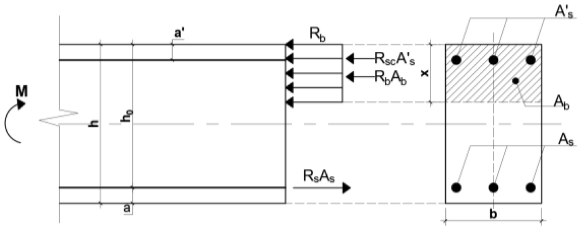


Figure 4. Internal Force and Stress Diagrams in the Cross Section of a Reinforced Concrete Beam [8]

Based on the sectional analysis method as shown in Figure 4, the standard of TCVN 5574:2018 specifies that, in calculating the flexural strength of reinforced concrete sections, the areas of tension reinforcement, A_s, and compression reinforcement, A_s', must satisfy the following condition

$$M \leq M_u \qquad \text{Eq. 1}$$

In the case of a rectangular beam cross section with doubly reinforced steel, the tension reinforcement A_s is equal to the compression reinforcement A_s'. The ultimate Moment Mu can be determined by eq. 2

$$M_u = R_s A_s \left(h_o - a'\right) \qquad \text{Eq. 2}$$

Where a’ is the conver concrete depth of compression fiber.

Based on TCVN 5574:2018, the calculation scheme for a doubly reinforced rectangular section ($A_s = A_s'$) in the design of RC beams under flexure is introduced, serving as the foundation for the VBA Excel programming algorithm presented in Figure 5.

$$A_s = \frac{M_x}{R_s \varsigma h_o} \qquad \text{Eq. 3}$$

Where ς is the calculated coefficient for the longitudinal bar section area A_s, and $h_o = h - a$ is the effective height.

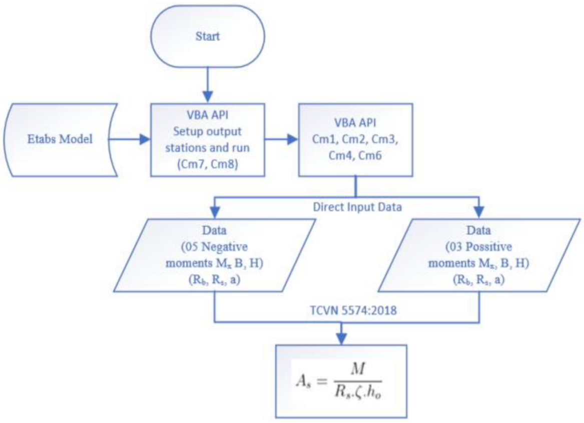


Figure 5. Flowchart for Designing the RC Beams in Flexure resistance

Shear Strength Resistance:

When designing according to the inclined-section model, it is essential to ensure both the load-carrying capacity and durability of the structural component along inclined sections subjected to shear forces and bending moments. Maintaining the strength of these inclined sections plays a key role in preserving the overall stability and safety of the load-bearing member.

The calculation of shear strength in an inclined section is based on balancing the external shear force with the internal shear resistance. Shear resistance in an inclined section comprises contributions from the concrete’s capacity to resist shear and from transverse reinforcement. In particular, the tensile capacity of the concrete and the reinforcement plays a critical role in determining the member’s ultimate resistance along the inclined section, as shown in Eq.4. The Figure 6 presents the algorithmic flowchart for designing the shear resistance of reinforced concrete beams in accordance with TCVN 5574:2018.

$$Q \le Q_{b,1} + Q_{sw,1} \qquad \text{Eq. 4}$$

Where: Q denotes the external shear force; $Q_{b,1}$ is the concrete shear capacity; $Q_{sw,1}$ is the shear contribution provided by the transverse reinforcement (or stirrups).

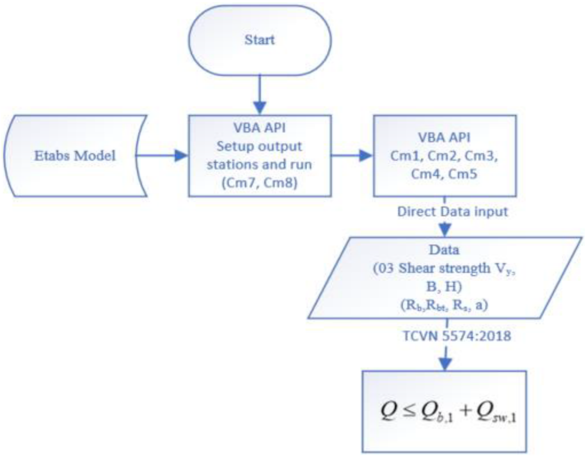


Figure 6. Flowchart for Designing the RC Beams in Shear resistance

2.4. Design Execution Workflow

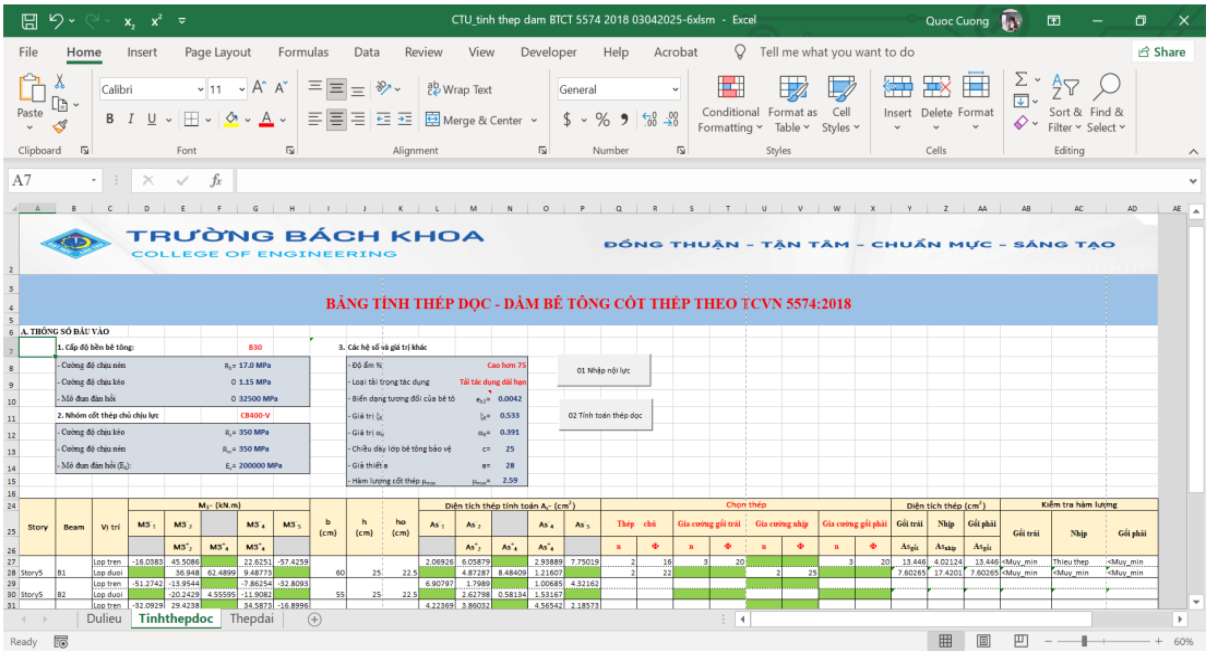
- Modeling or opening an existing ETABS model.
- Activate VBA macros, which automatically retrieve analysis results through the CSi API
- Set up output stations and run structural analysis to obtain internal forces.
- Input selected beam data from Etabs.
- Compute the required reinforcement according to TCVN 5574:2018.

- Generate output reports

3. RESULTS AND DISCUSSION

3.1. Verification

The programmed spreadsheet is illustrated in Figure 7, featuring two individual sheets for the design checks: one for flexural strength and one for shear strength. In the flexural design sheet, the tension steel is calculated to satisfy negative moments at five sections, while reinforcement for positive moments is determined at four locations, as depicted in Figure 1.



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BẢNG TÍNH THÉP DỌC - DẦM BÊ TÔNG CỐT THÉP THEO TCVN 5574:2018

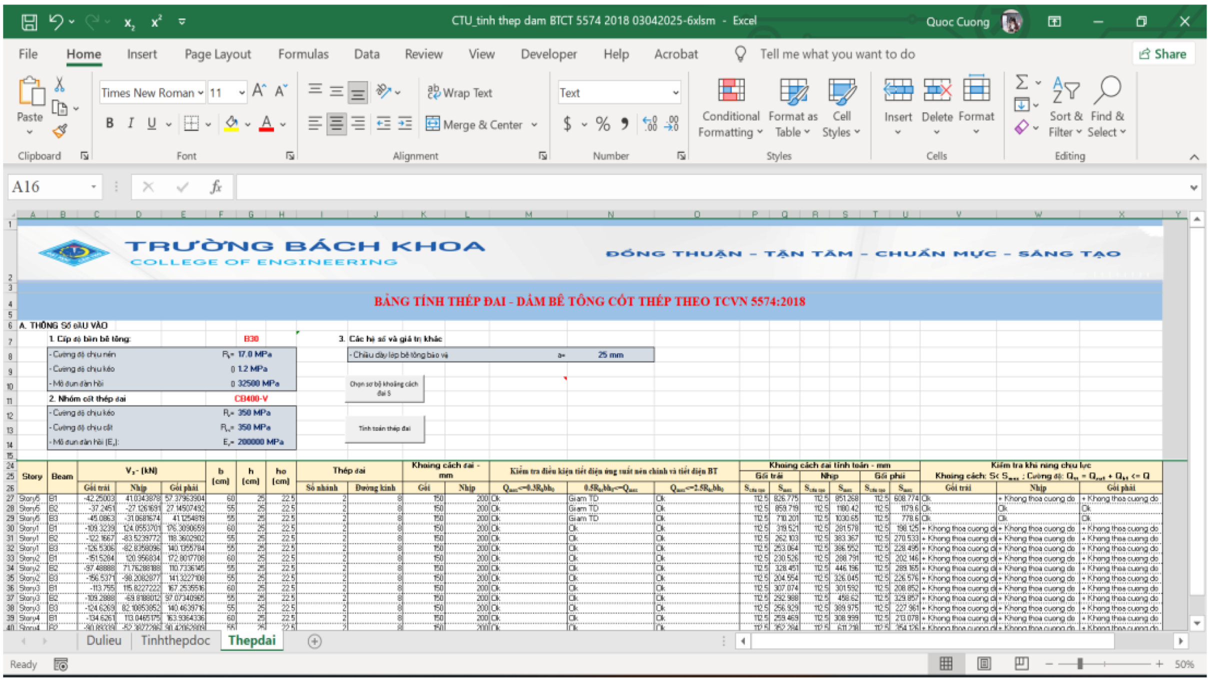
A. THÔNG SỐ ĐẦU VÀO

1. Cấp độ bền bê tông: B30
- Cường độ chịu nén R_b= 17.0 MPa
- Cường độ chịu kéo 0 1.15 MPa
- Mô đun đàn hồi 0 32500 MPa

2. Nhóm cốt thép chủ chịu lực CB400-V
- Cường độ chịu kéo R_s= 350 MPa
- Cường độ chịu nén R_{sc}= 350 MPa
- Mô đun đàn hồi (E_s): E_s= 200000 MPa

3. Các hệ số và giá trị khác
- Độ ẩm % Cao hơn 75
- Loại tải trọng tác dụng Tải tác dụng dài hạn
- Biến dạng tương đối của bê tô ε_{b2}= 0.0042
- Giá trị ξ_R ξ_R= 0.533
- Giá trị α_R α_R= 0.391
- Chiều dày lớp bê tông bảo vệ c= 25
- Giả thiết a a= 28
- Hàm lượng cốt thép μ_{max} μ_{max}= 2.59

a. Excel spreadsheet for flexural resistance design



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BẢNG TÍNH THÉP ĐAI - DẦM BÊ TÔNG CỐT THÉP THEO TCVN 5574:2018

A. THÔNG SỐ ĐẦU VÀO

1. Cấp độ bền bê tông: B30
- Cường độ chịu nén R_b= 17.0 MPa
- Cường độ chịu kéo 0 1.2 MPa
- Mô đun đàn hồi 0 32500 MPa

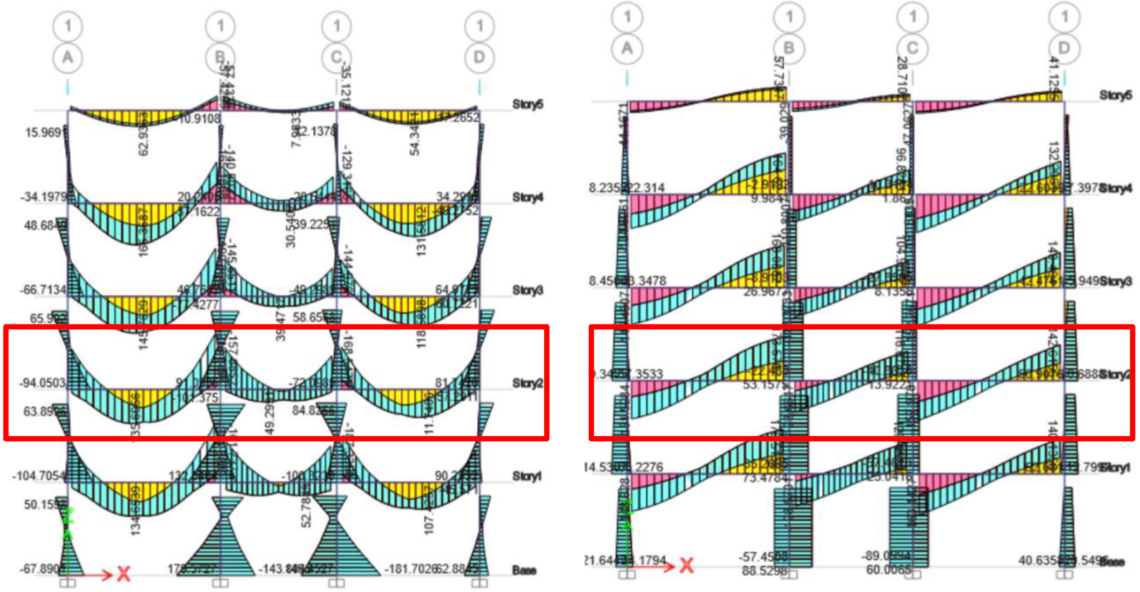
2. Nhóm cốt thép đai CB400-V
- Cường độ chịu kéo R_s= 350 MPa
- Cường độ chịu cắt R_{sw}= 350 MPa
- Mô đun đàn hồi (E_s): E_s= 200000 MPa

3. Các hệ số và giá trị khác
- Chiều dày lớp bê tông bảo vệ a= 25 mm

b. Excel speardsheet for shear resistance design

Figure 7. Spreadsheet interface

Figure 8a presents the planar frame model utilized for the example, and Figure 8b shows the corresponding bending moment and shear force diagram..



a. Moment diagrams (kN.m) b. Shear diagrams (kN)

Figure 8. An example of RC frame

Select beam story 2 to proceed with calculation. For convenience in calculation, we mark the beams from left to right with characters from B1 - B3. Using a Laptop with a an i7-8th CPU, 16GB RAM, and 8GB VGA, the total time of data input, processing, and calculation for 3 beams takes only 4 seconds (excluding the manual time for clicking tool buttons in Excel). Otherwise, This task would take more time if done manually, from extracting data, selecting the section moment, designing, to choosing the maximum longitudinal steel content. The results of calculating the reinforcement according to moment and shear force are presented in Table 1 and Table 2.

Table 1: Calculation of bending reinforcement of beam story 2

Story	Beam	Location	M_3- (kN.m)					Using the CSi API integrated with VBA Excel					Calculus		
								Design steel area A_s- (cm^2)					Design steel area A_s- (cm^2)		
			$M3^-_1$	$M3^-_3$	-	$M3^-_5$	$M3^-_7$	As^-_1	As^-_3	-	As^-_5	As^-_7	As^-_1	-	As^-_5
			-	$M3^+_2$	$M3^+_4$	$M3^+_6$	-	-	As^+_2	As^+_4	As^+_6	-	-	As^+_4	-
2	B1	Negative	-158.77	3.95	-	-17.06	-218.89	24.88	0.50	-	2.20	39.99	24.88	-	39.99
		Possitive	-	90.52	129.98	59.32	-	-	12.73	19.36	8.02	-	-	19.36	-
	B2	Negative	-157.89	-49.22	-	-33.08	-133.23	25.43	6.61	-	4.36	20.37	25.43	-	20.37
		Possitive	-	38.60	43.11	37.93	-	-	5.12	5.75	5.03	-	-	5.75	-
	B3	Negative	-168.55	-2.68	-	3.81	-134.43	27.86	0.34	-	0.49	20.60	27.86	-	20.60
		Possitive	-	44.54	106.61	76.59	-	-	5.95	15.55	10.67	-	-	15.55	-

Table 2: Calculation of shear reinforcement for beam story 2

Story	Beam	V_3- (kN)			b (cm)	h (cm)	ho (cm)	Stirrups		Spacing of stirrups - mm		Check the main compressive stress section condition and concrete section			Calculated stirrup spacing - mm						Test load capacity Spacing: $S< S_{max}$; Strength: $Q_{tt} = Q_{sw1} + Q_{b1} <= Q$		
															Left bearing		Span		Right bearing				
		Left bearing	Span	Right bearing				Branch number	Diameter	Beam bearing	Span	$Q_{max}<=0.3R_bbh_0$	$0.5R_{bt}bh_0<=Q_{max}$	$Q_{max}<=2.5R_{bt}bh_0$	$S_{constitute}$	S_{max}	$S_{constitute}$	S_{max}	$S_{constitute}$	S_{max}	Left bearing	Span	Right bearing
Story2	B1	-151.53	121.73	173.57	60	25	22.5	4	8	80	120	Ok	Ok	Ok	112.50	230.53	112.50	286.97	112.50	201.25	Ok	Ok	Ok
Story2	B2	-123.66	-85.34	116.67	55	25	22.5	4	8	110	150	Ok	Ok	Ok	112.50	258.93	112.50	375.22	112.50	274.44	Ok	Ok	Ok
Story2	B3	-157.98	-99.65	142.62	55	25	22.5	4	8	100	150	Ok	Ok	Ok	112.50	202.69	112.50	321.33	112.50	224.52	Ok	Ok	Ok

The spreadsheet efficiently addresses the reduction of longitudinal bar reinforcement at sections 3-3 and 5-5 for negative moments, and at sections 2-2 and 6-6 for positive moments. Specifically with Beam B2:

- The steel ratio designed to resist negative moments can be reduced by approximately 74% at cross section 3-3, and by 78.6% at cross section 5-5.

- The steel ratio designed to resist positive moments can be reduced by approximately 10.9% at cross section 2-2, and by 12.6% at cross section 6-6

For shear strength design, the shear forces determined at cross sections 3-3 and 5-5 are used to automatically compute the distance *a* and compare it with the 2.5*h*o limit specified in TCVN 5574:2018, ensuring that the appropriate formula is selected. By considering cross sections 3-3 and 5-5, the design procedure provides a safer and more precise verification of shear capacity than the traditional method of checking only one location at mid-span (cross section 4-4).

- The calculation results indicate that for the segment from the left support (cross section 1-1) to cross section 3-3, the stirrups of D8 with 4 branchs (n = 4) at 110 mm spacing adequately satisfy the design requirements for shear capacity.
- From cross section 3-3 to cross section 5-5, the stirrups of D8 with 4 branchs (n = 4) spaced at 150 mm also meet the design requirements.
- From cross section 5-5 to the right support (cross section 7-7), stirrups of D8 with 4 branchs (n = 4) at 110 mm are fully adequate.

The above results demonstrate that integrating the CSi API into Excel is highly effective for controlling both longitudinal reinforcement and stirrups in beams. In particular, it allows engineers to directly select beam elements from ETABS and simultaneously design reinforcement for multiple beams. Compared to conventional approaches, this workflow not only increases speed but also enhances accuracy in the design process.

3.2. Discussion on efficiency and stability Analysis

A key objective of the implemented workflow is to minimize manual operations in reinforced concrete beam design. Before the integration of VBA and the CSi API, engineers typically performed the following steps:

- Exporting Analysis Results: Manually exporting bending moments and shear forces into intermediary files or spreadsheets.
- Reformatting Data: Copying, pasting, and organizing internal forces into standardized tables for design calculations.
- Performing Hand or Spreadsheet-Based Computations: Using standalone Excel formulas or manual checks to finalize steel areas.
- Iterative Revisions: Repeating the export–import cycle whenever the ETABS model was modified or load combinations were updated.
- Examine the degree of automation: compare the number of steps or processing time before and after implementing the proposed method.

By contrast, the new VBA-CSi API workflow automatically retrieves internal forces for each beam via direct calls from Excel to ETABS, and processes these data with code-based design formulas. As a result:

- Redundant Steps Reduced: The export and reformatting of structural results are no longer needed.
- Rapid Iterations: Any update to the ETABS model can be reflected simply by re-running the Excel macro, which refreshes the beam design in seconds.

On the other hand, Reliability in structural design significantly depends on accurate input data. In a conventional design approach, engineers often face transcription errors when copying moment or shear results from ETABS output tables. Such errors can lead to incorrect steel bar requirements or even unsafe designs.

To quantify performance, two main metrics were tracked: Time saving and update Frequency

- Time Savings: The duration from obtaining final analysis results in ETABS to calculate steel bar schedules in Excel decreased. Larger savings were reported in projects with frequent design revisions, where iterative changes otherwise would require repeated manual data transfers.

- Update Frequency: With the integrated approach, running one macro refresh in Excel automatically recalculates steel requirements for all beams. In the case of a larger building with the significant beam elements, the entire process-from reading updated ETABS forces to calculate the bar schedules, taking faster compared to the manual method which using VBA excel or through an intermediate Access database file.

3.3. Limitations

Despite its demonstrated efficiency and accuracy, certain constraints remain when employing the CSi API for automated design workflows:

- CSi API, while powerful, is relatively new and not extensively documented compared to other well-established software development kits. The available reference materials and user guides often lack detailed examples, limiting developers' ability to explore advanced customization or troubleshoot less common issues.
- In some cases, only a limited set of functions or calls may be exposed through the API. This can impede the ability to implement certain design or analysis workflows that are readily available in the main ETABS user interface. Consequently, developers might need to rely on time-consuming workarounds or supplementary steps outside the API.
- The functionality of the CSi API can vary between different software versions. For example, newer ETABS releases may introduce or deprecate certain commands, creating a risk of incompatibility and necessitating ongoing updates to the VBA code.

4. CONCLUSIONS AND FUTURE WORK

This paper presented a streamlined approach to reinforced concrete (RC) beam design using the CSi API integrated with Excel VBA in accordance with TCVN 5574:2018. The proposed method automates the transfer of analysis results from ETABS to Excel, then applies standardized code-based calculations for both flexural and shear reinforcement.

The proposed solution embeds TCVN 5574:2018 design criteria into automated VBA subroutines, ensuring that all reinforcement calculations meet the national standard. Direct interaction with ETABS via the CSi API substantially cuts down on export–import steps, thereby reducing transcription errors and increasing design consistency. Furthermore, uniform application of the design formulas to each beam element streamlines iterative processes, offering engineers a reliable and up-to-date method for code-compliant design.

Implementing this automated system has demonstrated notable time savings and improved accuracy. Manual input steps and repetitive calculations are significantly reduced, enabling faster project turnaround and greater confidence in the results. The ease of updating ETABS models and re-running the Excel VBA macros further enhances productivity by simplifying design revisions-a critical advantage in large or evolving projects.

Future efforts may focus on extending this framework to other RC components, such as columns, slabs, and foundations, aiming for comprehensive automation of entire structural systems. More advanced analyses, including seismic and dynamic checks, could also be integrated to address a broader range of design considerations. Finally, incorporating optimization algorithms-such as genetic or gradient-based methods-holds potential for refining structural dimensions and reinforcing details, further optimizing material usage while maintaining full compliance with design codes.

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