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Evaluation of Software Applications in Structural Design Practice

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ABSTRACT

The integration of sophisticated software applications has fundamentally transformed structural design, allowing engineers to model complex geometries and perform high-speed simulations. However, the increasing reliance on "black-box" software introduces risks related to user error, over-reliance on automated outputs, and potential discrepancies between different software algorithms. This project provides a comprehensive evaluation of widely used structural design software (such as ETABS, SAP2000, STAAD.Pro, and Revit) to assess their reliability, ease of use, and precision..

The integration of advanced software applications has significantly transformed structural design practices, enabling engineers to model complex geometries and perform high-speed analytical simulations with greater efficiency. However, the increasing dependence on such “black-box” software introduces potential risks, including user errors, over-reliance on automated outputs, and inconsistencies arising from variations in software algorithms.

This project presents a comprehensive evaluation of widely used structural design software, including ETABS, SAP2000, STAAD.Pro, and Revit, with the objective of assessing their reliability, user-friendliness, and computational accuracy.

The study employs a comparative methodology, where a standardized multi-storey building frame is designed using multiple software platforms and manual calculations. Key parameters evaluated include bending moments, shear forces, displacement values, and material quantity estimations. Furthermore, the research investigates the interoperability between analysis software and Building Information Modeling (BIM) tools, highlighting bottlenecks in data transfer that often lead to design inconsistencies.

The findings reveal that while software significantly reduces computation time and human calculation error, the lack of rigorous manual verification remains a critical vulnerability in modern practice. The project concludes with a proposed framework for "Best Practices in Software Validation," emphasizing the necessity of bench-marking results and maintaining a strong theoretical foundation to ensure structural safety and regulatory compliance.
The findings indicate that while software tools significantly reduce computation time and minimize manual calculation errors, the absence of thorough manual verification remains a critical concern in modern engineering practice. The study concludes by proposing a framework for “Best Practices in Software Validation,” emphasizing the importance of result benchmarking and a strong theoretical foundation to ensure structural safety, accuracy, and compliance with engineering standards.

Keywords — AutoCAD, Tekla Tedds, Structural Design, Structural Beams, Eurocodes, UK Construction Standards, Drafting, Structural Analysis

1. INTRODUCTION

Structural engineering is a fundamental discipline that ensures the safety, stability, and serviceability of modern construction projects. With rapid advancements in digital technology, the design and analysis of structural elements—such as beams, columns, and joists—have evolved significantly, enabling engineers to achieve higher levels of accuracy, efficiency, and reliability. In the United Kingdom, structural design is governed by well-established standards, including British Standards (BS codes) and national building regulations, which mandate strict adherence to safety and performance criteria throughout the design process.

This study focuses on the application of advanced engineering software tools, namely AutoCAD and Tekla Tedds, in the design and analysis of structural components for a residential house extension project. AutoCAD is extensively used for the development of precise 2D and 3D drawings, facilitating effective visualization and clear communication of design intent. In contrast, Tekla Tedds serves as a powerful computational tool for performing detailed structural calculations, including load assessment, bending moment and shear force analysis, as well as deflection verification, ensuring compliance with relevant UK design standards such as BS 5950 for steel structures and BS 5268 for timber design.

The research is based on a practical case study from the UK, involving the design of timber roof joists, steel beams, and columns subjected to a range of loading conditions, including dead loads, imposed loads, and concentrated point loads. The integration of computational analysis tools with drafting software enhances workflow efficiency, minimizes the likelihood of human error, and promotes consistency in design outputs.

The primary objective of this paper is to illustrate how modern structural engineering software can be effectively leveraged to produce safe, economical, and code-compliant designs. Furthermore, the study emphasizes the importance of combining theoretical knowledge with digital tools to achieve reliable and practical solutions suitable for real-world construction applications.

Table 1.1 Literature Review

Software / Aspect	Research Findings	Research Gap
AutoCAD in Structural Drafting	AutoCAD is widely used for 2D drafting of structural elements like beams, columns, and layouts. It improves accuracy, reduces manual errors, and speeds up preparation of detailed drawings used in UK construction projects.	Limited automation in design calculations; requires manual input for structural analysis, leading to time consumption in complex projects.
Tekla Tedds in Structural Design	Tekla Tedds is used for automated structural calculations such as beam design, load analysis, and code-based verification (Eurocodes used in UK). It increases efficiency and ensures compliance with standards.	Dependency on predefined templates; less flexibility for unconventional or highly customized structural systems.

Integration of AutoCAD & Tekla Tedds	Combining AutoCAD (for drafting) and Tekla Tedds (for calculations) provides a complete workflow from design to detailing. Enhances coordination and reduces design time in structural projects.	Lack of seamless integration; data transfer between software may require manual intervention or additional tools.
Use in UK Construction Projects	Both software tools are widely adopted in UK engineering practices for structural beam design, ensuring compliance with British Standards and Eurocodes. Improves project efficiency and documentation quality.	Limited case studies on real-time project optimization and comparison with other BIM-based tools like Tekla Structures or Revit.
Structural Beam Design Using Software	Tekla Tedds automates beam design calculations including bending moment, shear force, and deflection checks. AutoCAD is used to prepare detailed beam drawings for execution.	Requires skilled professionals; errors may occur if input parameters are incorrect. Limited learning resources for beginners.

2. METHODOLOGY

2.1 METHODOLOGY FOR AUTOCAD

The methodology adopted for this project involves the design and analysis of structural beams and elements using AutoCAD and Tekla Tedds for a UK-based residential structure. The process includes understanding structural drawings, performing load calculations, analyzing members using software, and preparing final drawings in accordance with Eurocode standards. This approach ensures accuracy, safety, and proper documentation of structural components.

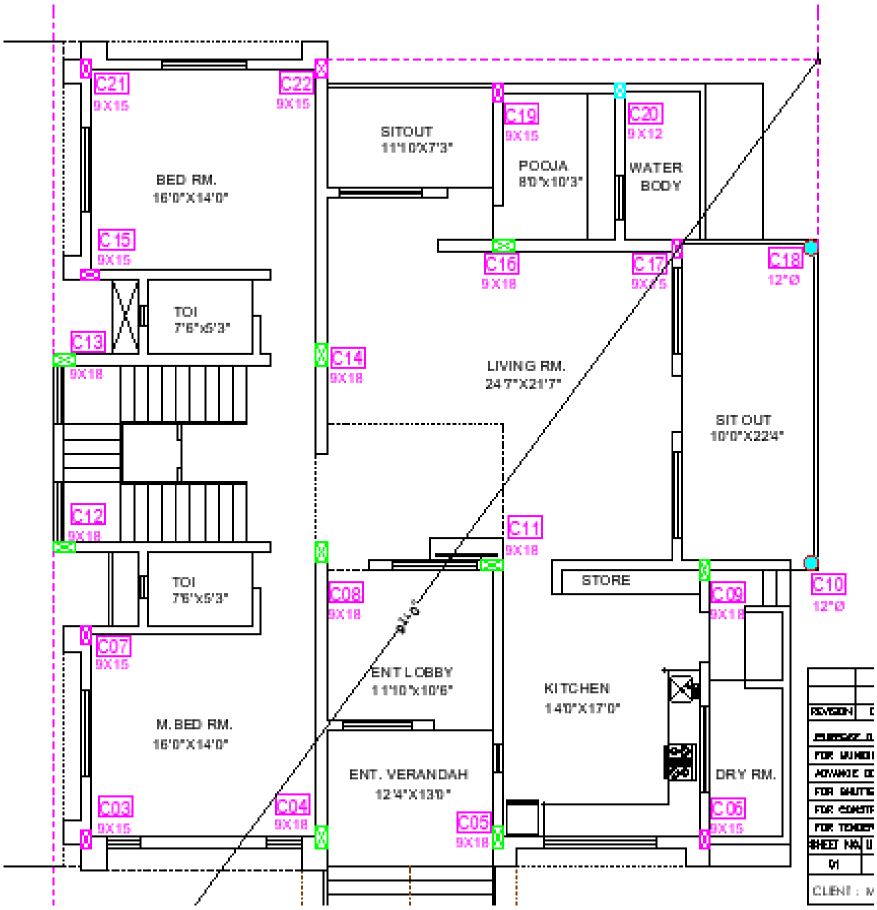


Fig. 2.1 Autocad

At the initial stage, all relevant project data and structural drawings were collected and studied thoroughly. This helped in understanding the arrangement of structural components such as beams, joists, lintels, padstones, and foundations. The drawings also provided important information regarding dimensions, spacing, and positioning of elements, which is essential for further analysis

After understanding the structural system, identification of various structural elements was carried out. Elements such as timber floor joists, steel beams (Universal Columns and Universal Beams), roof beams, and reinforced lintels were identified based on their function and location in the structure. This step is important to determine which elements require detailed design and analysis.

2.2 METHODOLOGY FOR TEKLA TEDDS

The methodology for Tekla Tedds involves designing and analyzing structural elements using input data from project drawings. Initially, parameters such as span, material properties, and support conditions are collected. Then, an appropriate design template (timber or steel beam) is selected in the software.

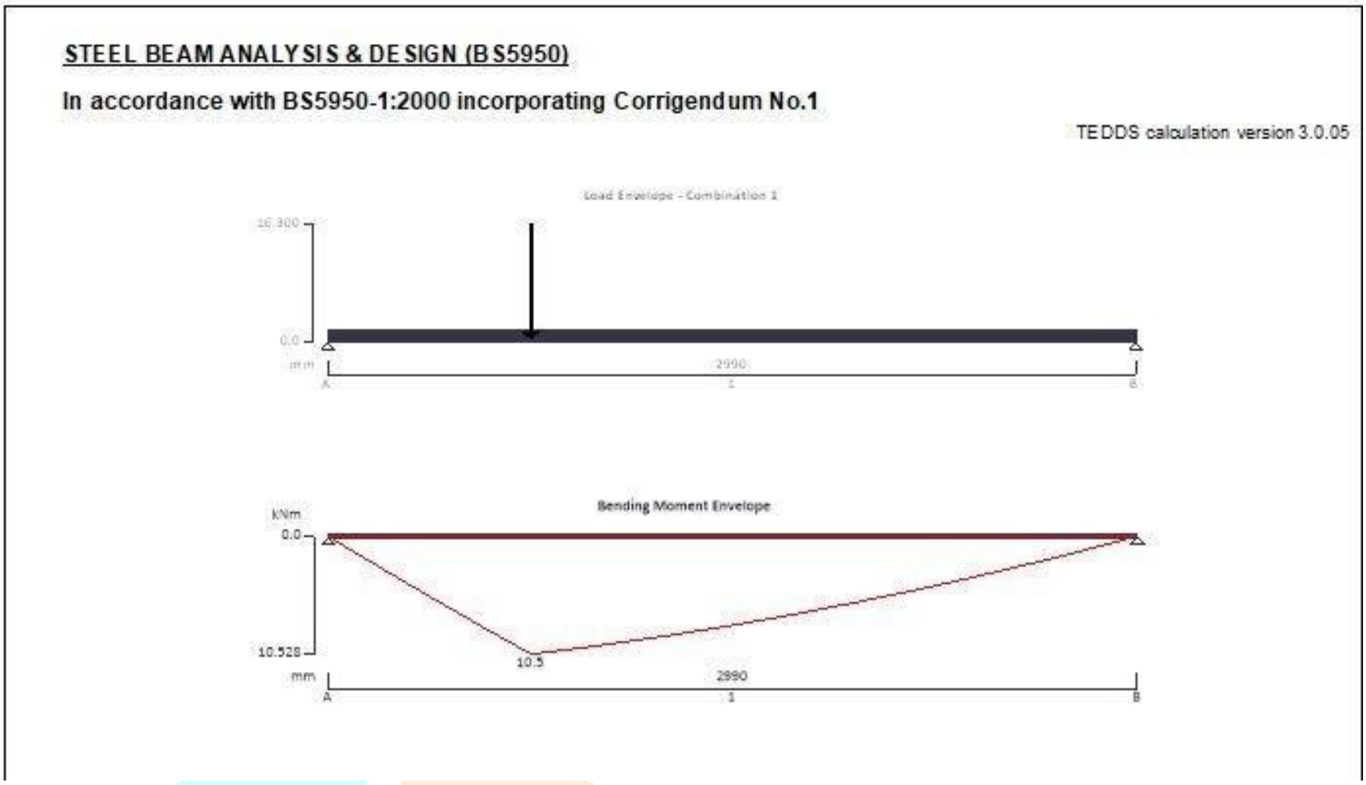


Fig. 2.2 Tekla Tedds

After that, loads including dead load and imposed load are applied. Tekla Tedds performs automatic calculations to determine bending moment, shear force, and deflection. The results are then checked against permissible limits as per Eurocode standards. Finally, the design is verified, and calculation reports are generated for documentation.

While using Tekla Tedds for structural design, some common errors may occur due to incorrect inputs or assumptions. One of the most common errors is wrong input data, such as incorrect span length, load values, or material properties, which can lead to unsafe or inaccurate results.

Another issue is improper load application, where dead load or imposed load is either missed or incorrectly applied. This directly affects bending moment and deflection calculations.

Selection of incorrect design template (for example, choosing a steel beam instead of a timber beam) can also produce wrong results.

2.3 LOADING SHEET USED FOR CALCULATIONS

The loading sheet is an important part of the structural design process, used to determine the loads acting on beams and other structural elements. It includes details of all types of loads such as dead load, imposed load, and roof load based on the project requirements.

The dead load consists of the self-weight of structural components like slabs, beams, walls, and finishes. The imposed load (live load) is taken based on the usage of the building, such as residential floor loads. Roof loads are also considered depending on the type and slope of the roof.

Total unfactored dead load	=	1.17	KN/m^2
Total unfactored imposed load	=	0.67	KN/m^2
Flat Roof			
Self weight of roof	=	0.8	KN/m^2
Imposed load on roof	=	0.75	KN/m^2
Total Unfactored Roof Dead Load	=	0.8	KN/m^2
Total Unfactored Roof Imposed Load	=	0.75	KN/m^2
Timber Floor			
Self weight of floor	=	0.5	KN/m^2
Imposed floor load	=	1.5	KN/m^2
Total Unfactored Dead Load	=	0.5	KN/m^2
Total Unfactored Imposed Load	=	1.5	KN/m^2
Internal Stud Wall Partition			
Self Weight	=	0.40	KN/m^2
Total Factored Dead Load = 0.4 x 1.4	=	0.56	KN/m^2

Fig. 2.3 Loading sheet

All these loads are calculated as per Eurocode standards used in the UK. The values obtained from the loading sheet are then used as input in Tekla Tedds for structural analysis and design. Proper preparation of the loading sheet ensures accurate results and safe design of structural members.

Brick walls act as load-bearing elements that transfer vertical loads such as self-weight and floor loads safely down to the foundation, while timber walls, being lightweight, mainly carry smaller loads and are used for partitions or light structural support. The chimney imposes a concentrated vertical load due to its self-weight and must be properly supported to ensure safe load transfer without causing stress on adjacent members. The staircase carries live loads from occupants and transfers these loads to supporting beams or walls. All these structural components contribute to the overall load distribution system of the building, ensuring that dead loads and imposed loads are safely transferred to the foundation.

Block / Cavity Wall			
Self Weight	=	3.80	KN/m^2
Total Factored Dead Load = 3.8 x 1.4	=	5.32	KN/m^2
Sky Light Load			
Self weight of Sky Light	=	1.5	KN/m^2
Imposed load On Sky Light	=	0.4	KN/m^2
Total Unfactored Dead Load	=	1.5	KN/m^2
Total Unfactored Imposed Load	=	0.4	KN/m^2
Chimney Wall Load			
Self Weight	=	2.40	KN/m^2
Total Factored Dead Load = 2.4 x 1.4	=	3.36	KN/m^2
Strength Of Existing Brickwork			
Cosidered as a old masonry	=	0.63	N/mm^2
Safe Ground Pressure			
Assumed Safe Ground Pressure	=	125.00	kN/m^2

Fig. 2.4 Loading sheet

2.4 Completion of the project

The project was successfully completed using AutoCAD and Tekla Tedds for the design and analysis of structural beams and elements in accordance with UK standards. The work involved different types of residential projects such as loft conversions, house extensions, and new dwelling houses, each requiring specific structural design considerations. All structural components were analyzed by considering loads such as dead load and imposed load to ensure accurate and safe design. Structural calculations were carried out using Tekla Tedds, and the results were verified to ensure compliance with Eurocode requirements. Detailed structural drawings, including beam layouts and sections, were prepared using AutoCAD for practical implementation. Finally, all calculations and drawings were compiled into a complete set of project documentation suitable for submission and approval.Steps for completion of projects

2.5 Steps for completion of the project

2.5.1 Structural drawing using Autocad

1. The first step in completing the project was architectural drawings, which provided detailed information about the building layout, dimensions, room arrangements, and overall structural planning. These drawings served as the foundation for further structural design, helping to understand the positioning of walls, beams, openings, and other elements required for analysis and modeling.

2. The second step involved cleaning and refining the architectural drawings by removing unnecessary elements such as dimensions, hatching, text, and other irrelevant objects. This process was carried out to simplify the drawing and make it suitable for structural work, ensuring better clarity and ease in identifying key elements like walls, openings, and structural components.

3. After cleaning the drawings, different elements were assigned company-specific colors to improve clarity and identification. For example, brown was used to represent loft areas, green for ground floor elements, and red for roof components. This color-coding system made it easier to distinguish between different parts of the structure, ensuring better understanding, coordination, and accuracy during the design and drafting process.
4. After assigning the colours, structural components such as timber flat roofs, pitched roofs, floor systems, joists, steel beams, and columns were placed in the drawings according to the architectural layout. These elements were carefully positioned to ensure proper load transfer and structural stability. Once placed, all components were reviewed and confirmed for further structural calculations, ensuring that the design inputs were accurate before proceeding to analysis in Tekla Tedds and MS Excel.

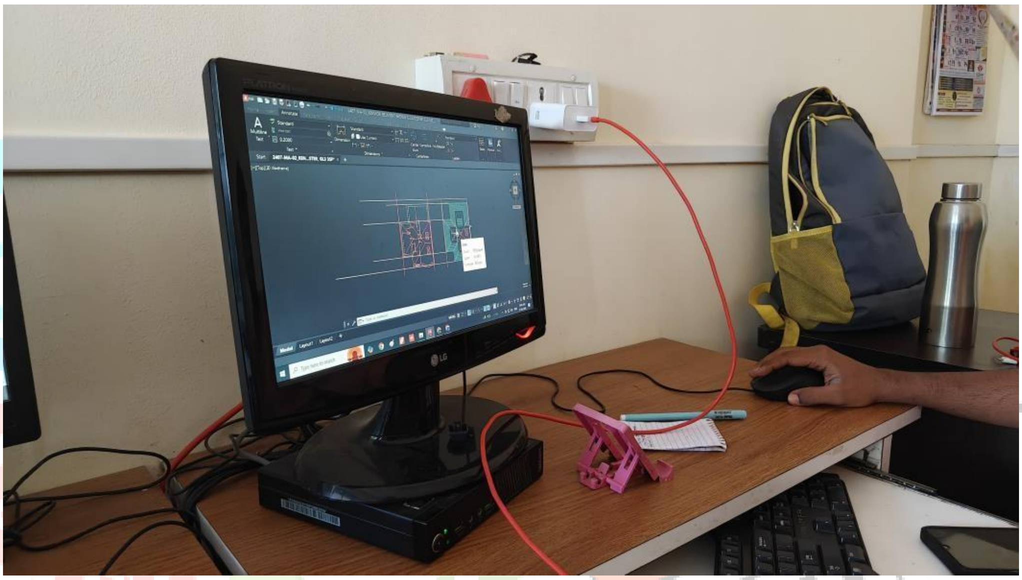


Fig. 2.5 Clearing architectural drawing

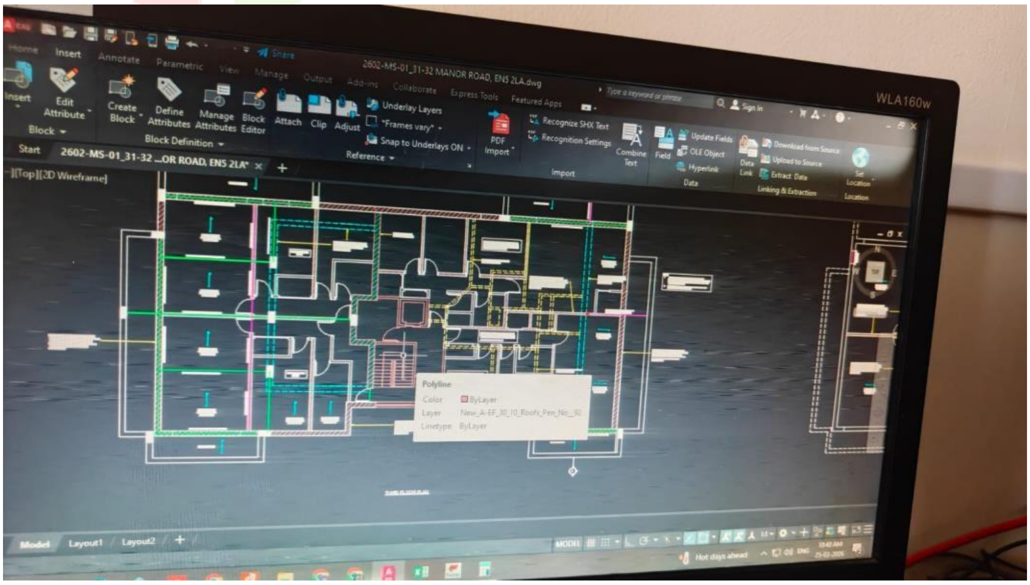


Fig. 2.6 Structural drawing

2.5.2 Structural Calculation with MS Excel and Tekla Tedds

1. The first step in the calculation process was to measure the span of the structural elements from the drawings and accurately input these values into the Excel sheet along with the roof angle. The span and roof angle are important parameters, as they directly influence load distribution and structural behavior, especially for pitched roofs.

2. After entering the span and roof angle, the next step was to input all relevant loads into the Excel sheet. These included dead loads, imposed loads, and roof loads as per design requirements. Once the data was entered, the Excel sheet was used to automatically calculate and combine different types of loads acting on the structural elements. This helped in determining the total design load, which is essential for accurate structural analysis and safe design.

3. After calculating the spans and loads in the Excel sheet, these values were then input into the appropriate Tekla Tedds design templates for each specific structural element. Depending on the type of member, such as timber joists, steel beams, or roof elements, the corresponding template was selected. The span, loading conditions, material properties, and support details were entered into Tekla Tedds to carry out detailed structural analysis.

4. After entering all the required inputs into Tekla Tedds, the structural checks were carried out to evaluate bending, shear, and deflection. If the results satisfied all the permissible limits, the design was marked as "PASS." Based on these results, the engineer then selected appropriate beam sizes that could safely support the applied loads while meeting design standards and practical requirements.

5. After selecting the appropriate beam sizes, these sizes were recorded in the Excel sheet for proper documentation and reference. The finalized beam and structural element sizes were also marked on the AutoCAD drawings to ensure accurate representation of the design. This step helped in maintaining consistency between calculations and drawings, making it easier for execution and verification during construction.

6. After finalizing the beam sizes and marking them in the drawings, the appropriate drawing sheet was selected for detailing. Detailed connection drawings of beams, columns, and foundations were then prepared and placed on the sheet. These drawings included connection details, dimensions, and specifications required for construction, ensuring proper load transfer and structural stability. This step is essential for clear communication between the design and construction teams.

7. After completing all drawings and calculations, the final project file was prepared and reviewed to ensure accuracy and completeness. The file, including structural drawings, calculation sheets, and design reports, was then sent to the project client for approval and further implementation. This step marked the completion of the design process and ensured that all required documents were properly communicated to the client.

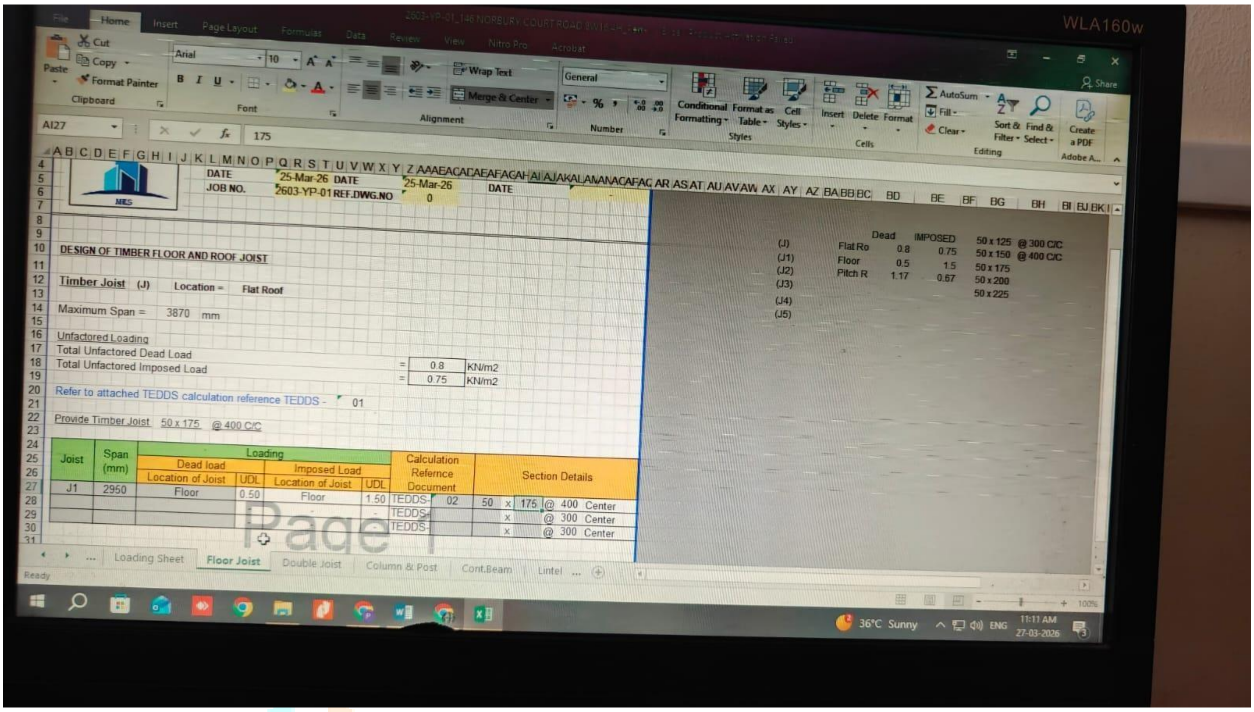
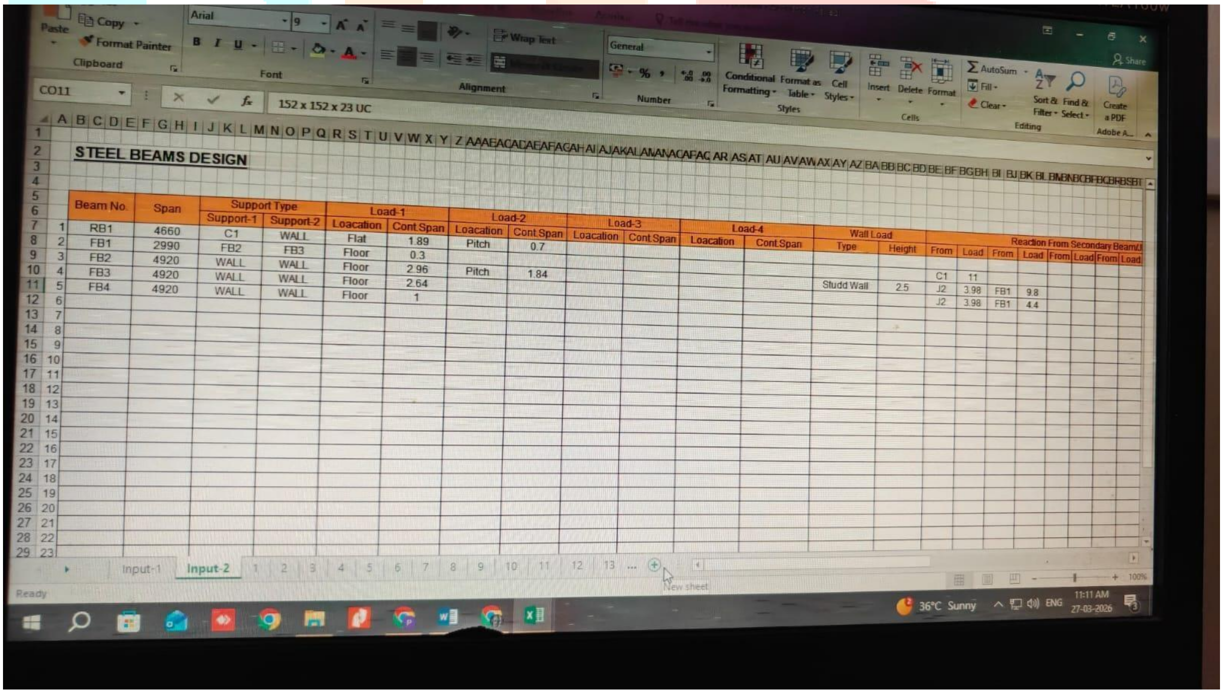


Fig. 2.7 MS Excel sheet for timber work and steel work



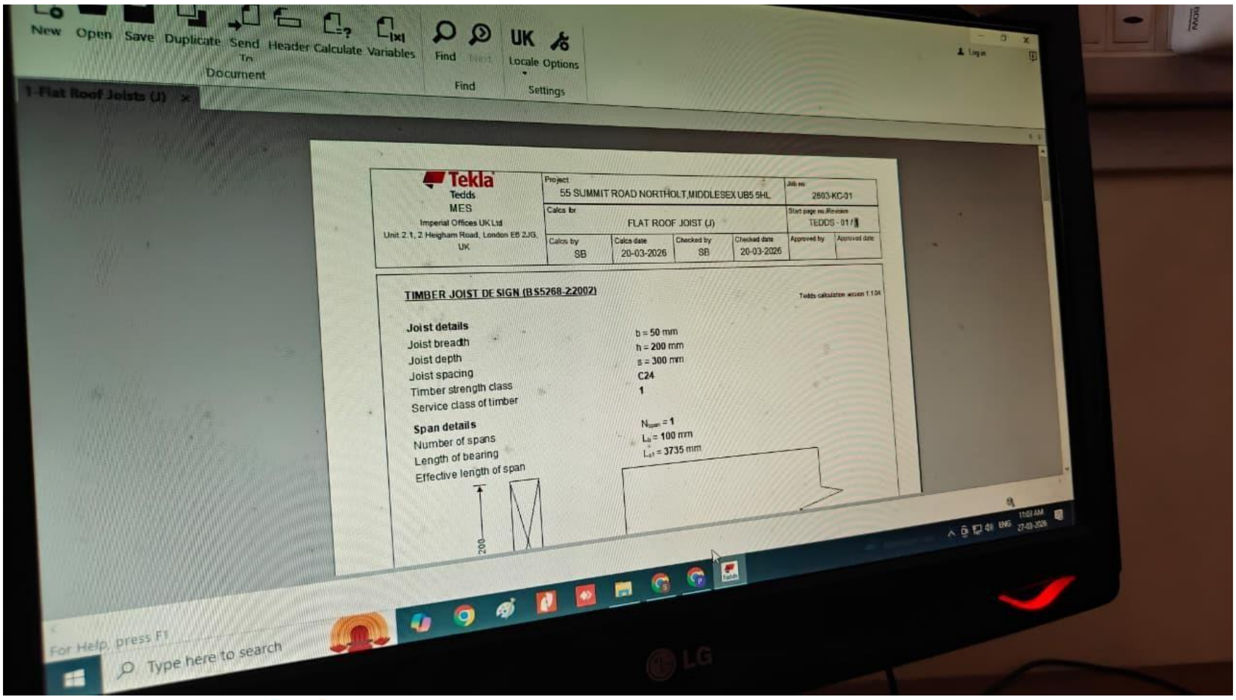


Fig. 2.8 Teds sheet for Timber work

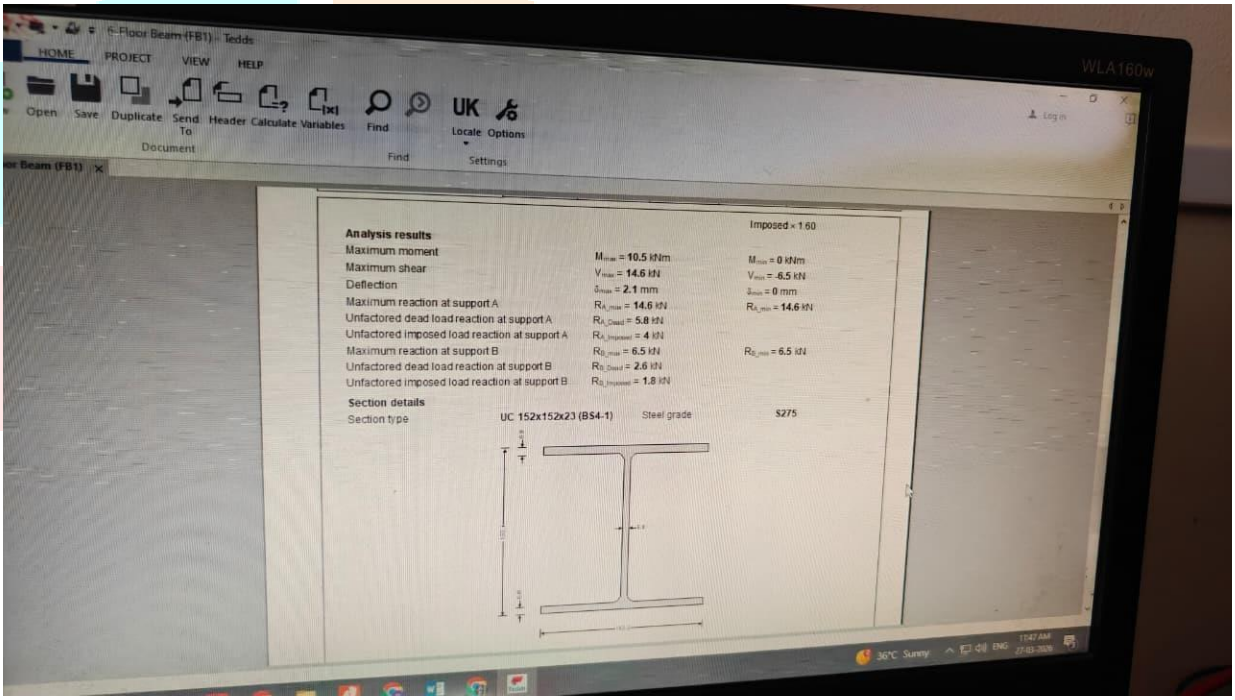


Fig. 2.9 Teds sheet for Steel beams

3. RESULT AND DISCUSSION

The results of the project were obtained through the design and analysis of structural beams and elements using Tekla Tedds, along with supporting calculations carried out in Excel sheets. Based on the input parameters such as span, loads, and material properties, the software provided values for bending moment, shear force, and deflection for each structural member. All the designed elements satisfied the required safety criteria, as the results showed a “PASS” condition in accordance with Eurocode standards.

The use of Excel sheets helped in accurately calculating and combining different types of loads, ensuring that the correct design loads were applied in Tekla Tedds. This improved the reliability of the analysis and minimized errors in the design process.

Through the results, it was observed that proper selection of beam sizes plays a crucial role in maintaining structural safety and efficiency. The selected timber and steel members were adequate to carry the applied loads without exceeding permissible limits. Deflection values were within acceptable ranges, ensuring serviceability of the structure.

The integration of AutoCAD and Tekla Tedds proved to be highly effective, as AutoCAD was used for detailed drawings, while Tekla Tedds provided accurate and quick structural calculations. This combination reduced manual effort and improved overall efficiency.

However, some errors may occur during the design process if proper care is not taken. These include incorrect input of span or load values in Excel or Tekla Tedds, improper selection of design templates, and wrong assumptions of support conditions. Additionally, errors in load calculation or missing load cases can lead to inaccurate results. Misinterpretation of software outputs or ignoring warning messages can also affect the final design.

Overall, the results demonstrate that the use of modern software tools leads to efficient and reliable structural design, provided that inputs are accurate and results are carefully verified.

3. CONCLUSION

- The project successfully demonstrated the use of AutoCAD and Tekla Tedds in the design and analysis of structural beams and elements for UK-based residential projects. The combination of these software tools helped in achieving accurate structural calculations and clear, detailed drawings required for practical implementation.
- The project successfully demonstrated the use of AutoCAD and Tekla Tedds in the design and analysis of structural beams and elements for UK-based residential projects. The combination of these software tools helped in achieving accurate structural calculations and clear, detailed drawings required for practical implementation.
- The project also highlighted the importance of correct input data, proper load assessment, and careful verification of results to ensure safe and effective design. The selected structural members were found to be adequate and satisfied all safety requirements as per Eurocode standards.
- Overall, the use of modern software tools improved the accuracy, reduced manual effort, and enhanced the efficiency of the structural design process. The project provided practical knowledge and experience in handling real-time structural design work, which is essential for professional engineering practice.

- The project also helped in understanding the importance of coordination between design calculations and drafting, ensuring that all structural details are accurately represented in the drawings.
- It provided insight into UK building regulations and Eurocode standards, improving knowledge of international design practices and their application in real projects.

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