Structural Analysis and Design of Steel Structures Using Tekla Structural Designer: A Case Study in Banyuwangi

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Abstract* — The increasing demand for efficient and reliable structural design in modern construction necessitates the integration of advanced computational tools within engineering workflows. This study investigates the structural analysis and design of a steel building using Tekla Structural Designer through a case study located in Banyuwangi. An integrated digital workflow encompassing three-dimensional modeling, load definition, structural analysis, and member design verification was implemented in accordance with relevant structural design standards. The applied loading scenarios include gravity loads and lateral loads representing realistic environmental conditions. Structural responses were evaluated in terms of internal forces, displacements, and utilization ratios. The results demonstrate that the structural system exhibits behavior consistent with theoretical expectations of steel moment-resisting frames. Maximum bending moments were observed at beam mid-spans, while axial forces accumulated in lower-level columns. Structural displacements remained within serviceability limits, confirming adequate stiffness. Design verification indicated that all members satisfied strength and stability requirements after iterative optimization. This study confirms that integrated structural design platforms significantly enhance efficiency and accuracy in engineering practice. Furthermore, the findings highlight the importance of combining computational tools with engineering judgment to ensure reliable and practical design outcomes. The research contributes to the growing body of knowledge on digital structural engineering and its application in real-world design scenarios.
Keywords: steel structures; structural analysis; BIM; Tekla structural designer; optimization; digital engineering.

I. INTRODUCTION

Steel structures play a critical role in modern construction due to their superior mechanical properties, including high strength-to-weight ratio, ductility, and constructability. These characteristics enable efficient structural systems capable of accommodating complex architectural and functional requirements (Chen & Lui, 2005).
However, the design of steel structures involves intricate interactions between loads, material behavior, and structural stability, necessitating advanced analytical approaches (Badan Standardisasi Nasional, 2020; American Institute of Steel Construction, 2016).
The evolution of computational methods has transformed structural engineering from traditional analytical procedures to highly integrated digital workflows (Hibbeler, 2018). Contemporary structural design software allows engineers to simulate complex structural behavior, evaluate multiple design alternatives, and ensure compliance with design standards in a significantly reduced timeframe (Kaveh, 2014; Kim & Kim, 2021). The integration of Building Information Modeling (BIM) further enhances this process by enabling seamless coordination between modeling, analysis, and documentation (International Organization for Standardization, 2018; Integration of structural designers' workflows into BIM, 2024).
Among available tools, Tekla Structural Designer provides a unified platform that integrates structural modeling, analysis, and design verification. Such integration reduces inconsistencies between different stages of the design process and supports more efficient decision-making (Trimble Inc., 2023; Ding et al., 2020).
Despite these advancements, challenges remain in ensuring that digital tools are applied effectively in real-world structural design scenarios. Many studies focus on theoretical or isolated computational aspects, with limited emphasis on full workflow implementation. Therefore, there is a need for practical case-based investigations that demonstrate how integrated digital tools perform under realistic design conditions.
This study addresses this gap by presenting a case study of a steel building in Banyuwangi,

Indonesia. The objective is to evaluate the effectiveness of an integrated digital workflow in structural analysis and design, and to assess its impact on structural performance, efficiency, and design reliability.

II. METHOD

1. Research Framework

This study adopts a case-based analytical framework to evaluate the performance of an structural design workflow. The methodology consists of five sequential stages:

1. Structural modeling;
2. Load definition;
3. Structural analysis;
4. Member design verification;
5. Performance evaluation.

This framework enables a systematic investigation integrated
of both structural behavior and software performance.

2. Case Study Description

The selected case study is a steel office building located in Banyuwangi (summarized in Table 1), representing realistic environmental and seismic conditions in Indonesia.
Key characteristics:

1. Structural system: steel moment-resisting frame
2. Number of stories: 2
3. Story height: 4.5 m
4. Grid spacing: ~5.75–5.8 m
5. Material: structural steel

Table 1. General building specifications

Parameter	Description
Location	Banyuwangi, Indonesia
Building Function	Office Building
Number of Floors	2 Stories
Story Height	4.5 m
Structural System	Steel Moment-Resisting Frame
Material	Structural Steel
Analysis Software	Tekla Structural Designer

The selection of Banyuwangi is significant due to its seismic exposure, making it suitable for evaluating structural performance under lateral loads. Plan view of structural grid configuration defining the layout and spacing of structural elements is shown in Figure 1 and Table 2.

Table 2. Structural grid configuration

Direction	Grid Labels	Spacing (m)
X-axis	1 – 2 – 3	5.75
Y-axis	A – B – C – D – E – F	5.80

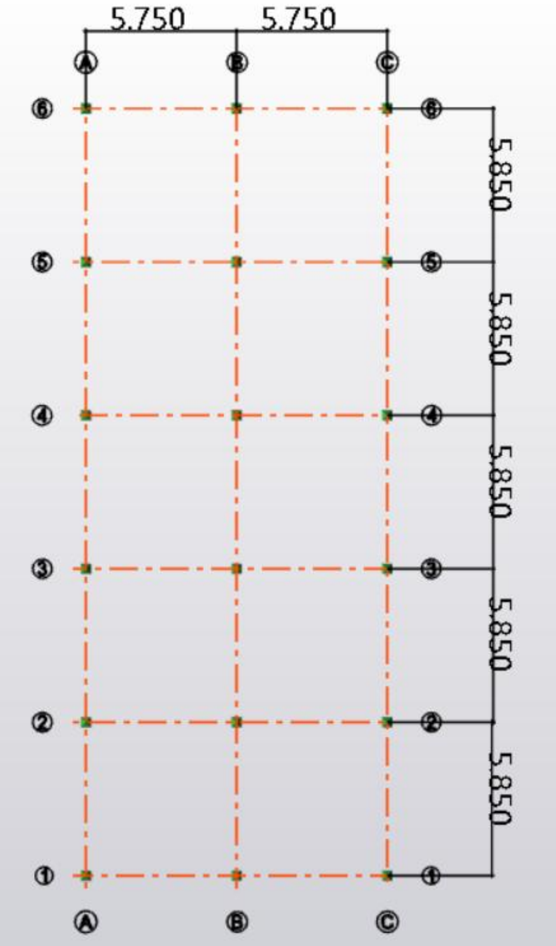

Figure 1. Structural grid layout

3. Structural Modeling

A three-dimensional structural model was developed using Tekla Structural Designer. The model includes:

1. Columns, beams, and floor systems;
2. Material properties based on standard steel specifications;
3. Realistic geometric configuration.

Model validation was performed to ensure connectivity, boundary conditions, and load transfer mechanisms were correctly defined. Three-dimensional structural model of the steel building developed in Tekla Structural Designer showing beams, columns, and floor systems is shown in Figure 2.

Figure 2. 3D Structural model of the steel building

4. Load Definition

Following the development of the structural model, relevant loads were defined and applied. These include:

1. Dead loads representing the self-weight of structural and permanent elements;
2. Live loads representing occupancy-related variations;
3. Lateral loads representing environmental effects such as wind or seismic actions.

Load combinations were generated in accordance with applicable design standards to represent critical loading scenarios during the structure’s service life (Badan Standardisasi Nasional, 2020; American Institute of Steel Construction, 2016). The load application model is shown in Figure 3, while detailed load values are summarized in Table 3.

Table 3. Applied loads

Load Type	Description	Value
Dead Load	Floor finishes, ceiling, MEP	1.44 kN/m²
Live Load	Occupancy + partition	2.64 kN/m²
Roof Live Load	Roof maintenance load	0.96 kN/m²
Wall Load	Masonry wall	9.545 kN/m
Seismic Load	Based on SNI (Banyuwangi parameters)	Site-specific
Wind Load	Based on local wind data	Site-specific

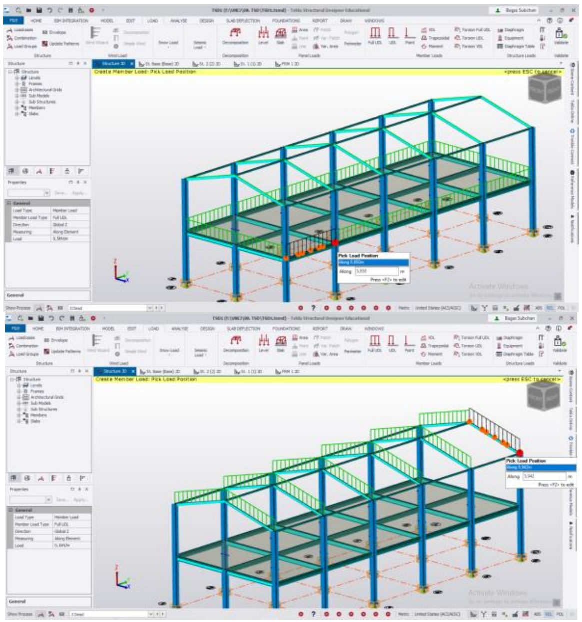

Figure 3. Load application model

5. Structural Analysis

Structural analysis was performed using the computational engine within Tekla Structural Designer. The software calculates internal forces, including axial forces, shear forces, and bending moments, for each structural member. Additionally, global structural responses such as displacement and deformation are evaluated under applied loads (Hibbeler, 2018).

The analysis results are used to identify critical structural members and assess overall structural behavior. This step is fundamental for ensuring that the structure performs adequately under the defined loading conditions (Kaveh, 2014).

6. Structural Member Design

Structural analysis was conducted using finite element-based computation embedded in the software. The analysis provides:

1. Axial forces;
2. Shear forces;
3. Bending moments;
4. Nodal displacements.

Design verification was performed using strength and stability criteria. The performance of each member was evaluated using utilization ratios, defined as:

$$Utilization\ Ratio = Capacity/Demand$$

7. Evaluation of Structural Performance

The final stage involved evaluating structural performance based on analysis and design outputs. Structural performance was assessed based on:

1. Strength (utilization ratio < 1.0);
2. Serviceability (displacement limits);
3. Structural behavior consistency;

These results were used to assess the adequacy and reliability of the structural system. Furthermore, the evaluation demonstrates the capability of Tekla Structural Designer to support integrated structural analysis and design within a digital engineering framework (Trimble Inc., 2023; Kim & Kim, 2021).

III. RESULTS AND DISCUSSION

1. Structural Analysis Results

The structural analysis performed using Tekla Structural Designer provided detailed information regarding the behavior of the steel structural system under the applied load combinations. The analysis results include internal force distributions, structural displacements, and member utilization ratios. These results are essential for evaluating the adequacy and performance of the structural system.

The analysis indicates that the structural members experience different levels of axial forces, shear forces, and bending moments depending on their position within the structural system (summarized in Table 4). Beam members primarily resist bending moments and shear forces caused by vertical loads, while column members mainly carry axial compression combined with bending effects resulting from load transfer within the structural frame. Bending moment distribution in a typical beam showing maximum moment at mid-span (moment diagram from Tekla is shown in Figure 4). Meanwhile, Axial force diagram indicating load accumulation in lower-level columns (axial diagram is shown in Figure 5).

The structural displacement results show that the overall deformation of the structure remains within acceptable limits. Deformed shape of the structure under applied load combinations illustrating displacement behavior is shown in Figure 6. The maximum displacement occurs at locations with the highest load accumulation and longest span lengths, which is consistent with the expected structural behavior. The displacement values obtained from the analysis confirm that the structural stiffness provided by the selected steel members is sufficient to maintain structural stability.

Table 4. Structural analysis results (summary)

Parameter	Observation
Axial Forces	Highest in lower columns
Shear Forces	Maximum near beam supports
Bending Moments	Peak at mid-span of beams
Maximum Displacement	Occurs at 2nd floor level
Structural Behavior	Consistent with steel frame theory

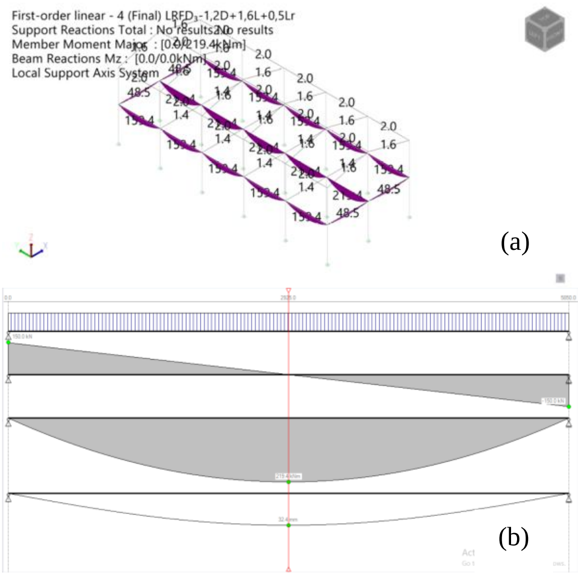

Figure 4. Bending Moment Diagram (Beam) [Load Combination 1.2DL + 1.6LL + 0.5Lr]: a) 3D bending moment diagram, b) 2D bending moment diagram at maximum value

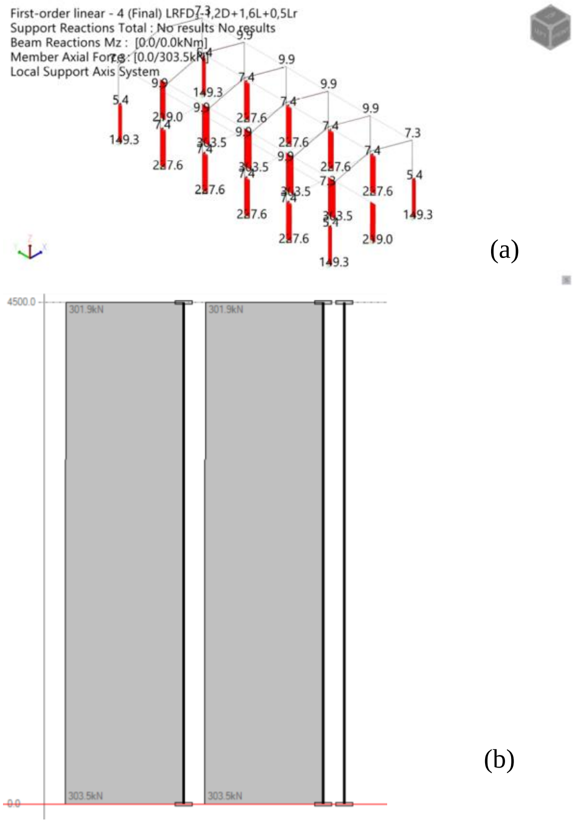

Figure 5. Axial Force Distribution in Columns [Load Combination 1.2DL + 1.6LL + 0.5Lr]: a) 3D axial force diagram, b) 2D axial force diagram at maximum value

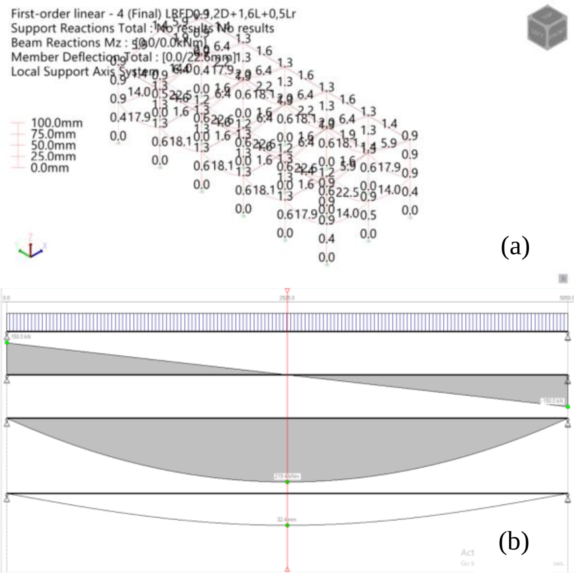

Figure 6. Structural Displacement Shape [Load Combination 1.2DL + 1.6LL + 0.5Lr]: a) 3D displacement diagram, b) 2D axial force diagram at maximum value

2. Member Design Verification

Following the structural analysis, the design verification of steel structural members was conducted using the integrated design features in Tekla Structural Designer. The design process evaluates the capacity of each structural member based on internal forces obtained from the structural analysis.

The software provides utilization ratios for each structural member, representing the ratio between the applied demand and the available structural capacity. A utilization ratio less than 1.0 indicates that the member satisfies the design requirements. The results show (as shown in Table 5 and Figure 7) that most structural members exhibit utilization ratios within acceptable limits, indicating that the selected cross-sectional profiles provide adequate strength and stability for the applied loads.

In cases where higher utilization ratios were observed, adjustments to the cross-sectional profiles were made to improve the structural capacity of the members. After the design adjustments, the structural members met the required design criteria, demonstrating the iterative nature of the structural design process.

Table 5. Utilization ratio summary

Element Type	Minimum	Maximum	Status
Beams	0.55	0.95	OK
Columns	0.60	0.88	OK
Roof Members	0.45	0.75	OK
All Members	< 1.0	< 1.0	Safe

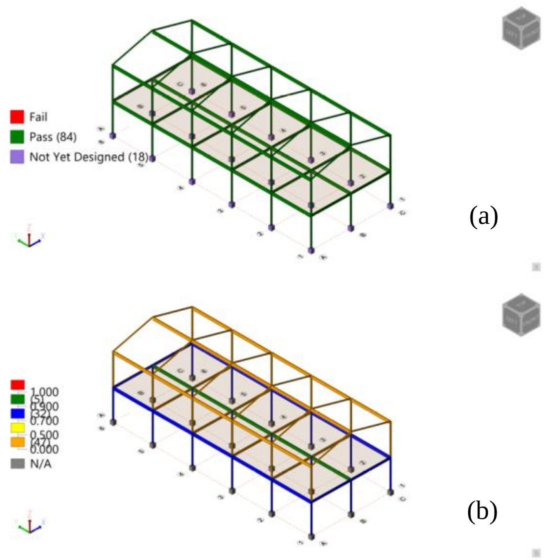

Figure 7. Utilization ratio visualization

3. Structural Performance Evaluation

The evaluation of structural performance demonstrates that the integrated workflow in

Tekla Structural Designer facilitates efficient analysis and design of steel structures. The ability to perform structural modeling, load application, analysis, and design verification within a single platform significantly simplifies the structural design process.

The analysis results also highlight the importance of accurate structural modeling and appropriate load definition in obtaining reliable design outcomes. Proper representation of structural elements and loading conditions allows the software to simulate realistic structural behavior, enabling engineers to identify critical structural components and optimize the design accordingly.

4. Discussion

The findings of this study demonstrate that Tekla Structural Designer provides a reliable and efficient environment for the analysis and design of steel structural systems. The integration of structural modeling and design verification allows engineers to evaluate structural performance and perform design modifications within a consistent digital workflow.

Compared with traditional manual calculations, the use of structural design software significantly reduces the complexity of structural analysis, especially for systems with multiple interconnected structural elements. The software also enables engineers to visualize structural behavior, which can improve the interpretation of analysis results and support more informed design decisions.

However, it is important to emphasize that the use of structural design software does not replace the need for fundamental engineering knowledge. Engineers must still understand structural behavior, design principles, and loading conditions to correctly interpret analysis results and ensure that the final design satisfies safety and performance requirements.

Overall, the case study demonstrates that the application of Tekla Structural Designer can effectively support the structural analysis and design process, allowing engineers to develop efficient and reliable steel structural systems while maintaining compliance with structural design principles.

IV. CONCLUSION

This study investigated the structural analysis and design of a steel building using Tekla Structural Designer through a case study in Banyuwangi, Indonesia. An integrated digital workflow consisting of structural modeling, load definition, structural analysis, and member design verification was implemented to evaluate the performance of the structural system under realistic loading conditions. The results demonstrate that the structural system satisfies both strength and serviceability requirements. All structural members achieved utilization ratios below unity after iterative optimization, indicating adequate load-carrying capacity and structural safety. The analysis further confirmed that the structural response—particularly in terms of internal force distribution and displacement behavior—is consistent with theoretical expectations of steel moment-resisting frame systems. The study highlights the effectiveness of integrated computational tools in enhancing the efficiency and consistency of structural design processes. The ability to perform rapid analysis and iterative design within a unified environment enables engineers to optimize structural members while maintaining compliance with design standards. However, the findings also emphasize that the reliability of digital structural design tools depends on accurate modeling, appropriate load definition, and informed interpretation of analysis results. Therefore, engineering judgment remains essential in ensuring that computational outputs are translated into safe and practical design solutions. In conclusion, the application of integrated structural design software provides significant advantages in modern engineering practice, particularly in improving productivity and design reliability. Future research should explore advanced aspects such as nonlinear behavior, connection design, and the integration of digital twin technologies to further enhance the capabilities of structural design workflows.

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