Cureus Journal of Engineering
https://doi.org/10.7759/s44388-026-00232-1

Original Article

Integrated Digital Workflow for Structural Design, Fabrication Documentation, and Quantity Estimation of an Industrial Steel Warehouse

Brajendra Singh [1,✉], Vasudev Rodwal [2], Priyanka Rajput [2]

1. *Department of Structural Engineering, Sage University, Indore, IND*
2. *Department of Civil Engineering, Sage University, Indore, IND*

Received: June 23, 2026 | Review began: June 30, 2026 | Review ended: July 09, 2026 | Published: August 20, 2026

Abstract

Accurate fabrication documentation and material quantity estimation are critical for the successful execution of industrial steel building projects. Conventional quantity estimation methods based on two-dimensional drawings and manual calculations frequently underestimate secondary structural members, connection components, and fabrication accessories, resulting in discrepancies between design and actual construction requirements. This study evaluates an integrated digital engineering workflow for structural design, fabrication documentation, and quantity estimation of an industrial steel warehouse by integrating structural analysis with Tekla Structures-based detailing and fabrication modeling.

A pre-engineered industrial warehouse measuring 23.4 m × 9.4 m with an eave height of 5.5 m was selected as the case study. Structural analysis and member design were performed using STAAD.Pro CONNECT Edition under dead, live, wind, and seismic loading in accordance with IS 875 (Parts 1-3): 2015, IS 1893 (Part 1): 2016, and AISC 360-16 (Allowable Strength Design). The finalized structural members were subsequently developed into a detailed three-dimensional fabrication model using Tekla Structures 2024, incorporating primary and secondary framing members, bracing systems, connection assemblies, bolts, and other fabrication components. Fabrication drawings, erection drawings, assembly drawings, and material quantity reports were generated directly from the coordinated BIM model and compared with conventional manual quantity estimation.

The integrated workflow produced a total estimated steel quantity of 12,960.92 kg, whereas conventional estimation yielded 11,930 kg. This represents an increase of 1,030.92 kg (8.64%) compared with conventional manual estimation due to the inclusion of secondary framing members, connection plates, foundation bolts, fasteners, cladding accessories, and other components that are commonly omitted or simplified in manual quantity take-offs. The integrated workflow also improved consistency between structural analysis, detailing, and fabrication documentation by reducing manual data transfer and minimizing coordination errors.

These findings demonstrate that the integration of structural analysis with Tekla Structures-based detailing provides more comprehensive quantity estimation, enhances fabrication documentation, and improves coordination throughout the design-to-fabrication process. Although the investigation is based on a single industrial warehouse case study, the proposed workflow provides a practical and reproducible framework for improving documentation quality and material estimation in industrial steel construction projects.

Categories: Structural Engineering

How to cite this article:
Singh B, Rodwal V, Rajput P (August 20, 2026) Integrated Digital Workflow for Structural Design, Fabrication Documentation, and Quantity Estimation of an Industrial Steel Warehouse. Cureus J Eng 3 : es44388-026-00232-1. DOI https://doi.org/10.7759/s44388-026-00232-1

Keywords: pre-engineered building (peb), staad.pro analysis, tekla structures modelling, structural design approach, quantity estimation, boq generation, connection detailing, steel structures)

Introduction

The demand for efficient, economical, and sustainable construction practices has increased significantly in recent years due to rapid industrialization, urban expansion, and infrastructure development. Steel structures have become a preferred choice for industrial buildings because of their high strength-to-weight ratio, durability, recyclability, and suitability for long-span applications. Compared with conventional reinforced concrete construction, steel structures provide faster erection, reduced foundation loads, improved quality control, and greater flexibility for future expansion. In the present study, structural loading was evaluated in accordance with IS 875 (Parts 1-3) and IS 1893 (Part 1):2016, while the structural steel members were designed using the provisions of ANSI/AISC 360-16 (Allowable Strength Design (ASD)). This combination of Indian loading standards and the AISC steel design specification reflects engineering practice commonly adopted for industrial steel building projects involving international detailing and fabrication workflows [1-6].

Industrial steel buildings increasingly rely on digitally integrated engineering workflows that combine structural analysis, three-dimensional detailing, fabrication documentation, and project information management [7]. Rather than treating structural analysis and detailing as separate activities, modern engineering practice emphasizes continuous information exchange between analytical and fabrication models. Such integration improves coordination among structural engineers, detailers, and fabricators, reduces design inconsistencies, and enhances the quality and completeness of engineering documentation throughout the project lifecycle [8]. Although integrated digital workflows are often associated with improvements in project cost and execution time, the present study focuses specifically on evaluating documentation quality, coordination, and material quantity estimation rather than quantifying economic or scheduling benefits.

Several researchers have reported that pre-engineered buildings (PEBs) provide significant advantages over conventional steel construction in terms of structural efficiency, fabrication, and project delivery. Comparative investigations have demonstrated reductions in structural weight and improved material utilization through optimized PEB systems [9]. Other studies have shown that PEBs satisfy structural safety requirements under seismic loading while maintaining economic efficiency [10]. Research has also confirmed that appropriate member selection, structural optimization, and advanced analysis techniques improve the performance of steel buildings subjected to combined wind and seismic actions [11]. These studies primarily focus on structural behavior and optimization rather than the integration of structural analysis with digital detailing and fabrication workflows.

The increasing adoption of advanced structural detailing software has significantly improved the preparation of fabrication documentation, assembly drawings, erection drawings, and material quantity estimation for steel structures. Tekla Structures is widely used for detailed three-dimensional modeling, steel detailing, fabrication drawing generation, assembly modeling, and automated quantity extraction [12]. The software enables the creation of fabrication-level structural models incorporating primary and secondary members, connection plates, bolts, welds, bracing systems, and other fabrication components required for manufacturing and site erection. Similarly, STAAD.Pro CONNECT Edition provides a comprehensive environment for structural analysis and code-compliant member design by evaluating structural response, internal forces, member adequacy, and overall structural performance under prescribed loading conditions [13].

Despite the widespread use of structural analysis and detailing software in engineering practice, most published studies investigate structural analysis and optimization or detailing software independently. Relatively few studies have examined the integration of STAAD.Pro CONNECT Edition and Tekla Structures are within a unified digital workflow that supports structural design, fabrication documentation, erection planning, and automated quantity estimation for industrial steel buildings. Furthermore, quantitative comparisons between conventional manual quantity estimation and automated quantity extraction remain limited, particularly for industrial warehouse structures.

Therefore, the present study investigates an integrated digital workflow linking STAAD.Pro CONNECT Edition and Tekla Structures 2024 for the structural design, fabrication documentation, and quantity estimation of an industrial steel warehouse. The study evaluates the effectiveness of integrating structural analysis, fabrication detailing, drawing generation, and automated material quantity extraction within a coordinated digital engineering workflow. The findings are intended to demonstrate improvements in documentation completeness, quantity transparency, and coordination between structural design and detailing activities. The investigation is based on a single industrial warehouse case study; therefore, the conclusions are limited to the selected structural configuration and provide a practical framework for future validation using additional industrial steel building projects. The overall three-dimensional digital model developed in Tekla Structures is illustrated in Figure 1.

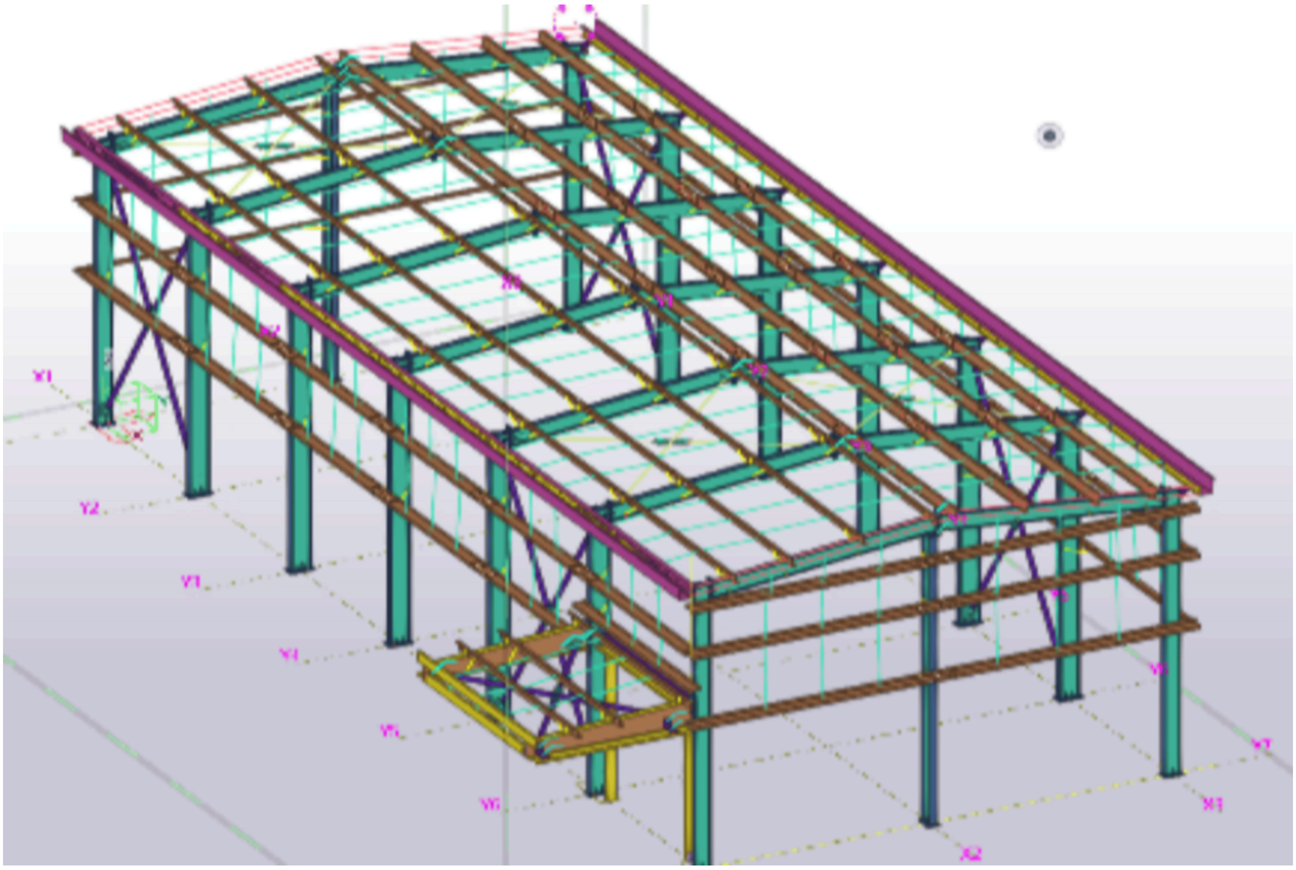

FIGURE 1: Illustrates the three-dimensional digital model of the industrial warehouse developed in Tekla structures

Objectives

The present study focuses on the integrated application of STAAD.Pro and Tekla Structures for structural analysis, detailing, fabrication documentation, and quantity estimation of a pre-engineered industrial warehouse. The objective is to evaluate how a digitally integrated workflow improves documentation consistency, coordination between structural analysis and detailing, and the completeness of quantity estimation.

1. To carry out a comprehensive structural analysis and design of a PEB using STAAD-Pro in compliance with relevant steel design standards.

2. To develop an accurate and detailed 3D model of the designed structure in Tekla Structures, including connection detailing and component-level modeling.

How to cite this article:
Singh B, Rodwal V, Rajput P (August 20, 2026) Integrated Digital Workflow for Structural Design, Fabrication Documentation, and Quantity Estimation of an Industrial Steel Warehouse. Cureus J Eng 3 : es44388-026-00232-1. DOI https://doi.org/10.7759/s44388-026-00232-1

3. To integrate the design and detailing workflow between STAAD-Pro and Tekla Structures for improved coordination and reduced design errors.

4. To generate fabrication drawings, assembly drawings, and erection plans from the Tekla model, ensuring accuracy, constructability, and ease of on-site implementation.

5. To perform accurate quantity estimation and prepare a comprehensive Bill of Quantities (BOQ) for primary and secondary structural members, connection components, foundation bolts, fasteners, cladding systems, and other fabrication accessories directly extracted from the coordinated Tekla Structures model.

Novelty of the study

The novelty of this research lies in the development and evaluation of an integrated digital engineering workflow that combines structural analysis, Tekla Structures-based detailing, fabrication documentation, and automated quantity estimation for an industrial steel warehouse within a single coordinated engineering environment. Unlike most previous studies, which primarily investigate either structural analysis and design or structural detailing independently, the present study demonstrates a complete design-to-fabrication workflow and quantitatively compares conventional manual quantity estimation with automated quantity extraction from the Tekla Structures model using a real industrial case study.

The major contributions of the study include:

Integration of STAAD.Pro CONNECT Edition for structural analysis and design with Tekla Structures 2024 for detailed three-dimensional structural modeling, fabrication documentation, and quantity estimation.

Development of a comprehensive three-dimensional structural model incorporating primary framing members, secondary framing members, bracing systems, connection components, bolts, foundation details, and other fabrication elements required for manufacturing and erection.

Automatic generation of fabrication drawings, assembly drawings, and erection drawings directly from the Tekla Structures model, ensuring consistency between structural design and fabrication documentation.

Automated extraction of a comprehensive BOQ, including primary and secondary structural members, connection plates, foundation bolts, fasteners, cladding systems, and other fabrication accessories, followed by a quantitative comparison with conventional manual quantity estimation.

Evaluation of the integrated workflow in terms of documentation completeness, quantity transparency, and coordination between structural analysis and detailing, demonstrating an 8.64% increase in the estimated material quantity compared with conventional manual estimation due to the inclusion of fabrication components that are commonly omitted or simplified during traditional quantity take-off.

Presentation of a practical and reproducible engineering methodology that integrates structural analysis, detailing, fabrication documentation, and automated quantity estimation within a single digital workflow for industrial steel warehouse projects.

Unlike previous studies that primarily evaluate structural optimization or individual software capabilities, the present research demonstrates the practical integration of STAAD.Pro CONNECT Edition and Tekla Structures 2024 throughout the structural design, detailing, fabrication documentation, and quantity estimation process. The proposed workflow is validated using an industrial steel warehouse case study and provides quantitative evidence of the advantages of an integrated digital engineering approach for improving documentation completeness and material quantity transparency. Although the investigation is limited to a single industrial warehouse, the proposed methodology provides a practical framework for future validation using additional industrial steel building projects.

Materials And Methods

The study adopted an integrated digital engineering workflow to analyze, detail, and estimate the material quantities of an industrial pre-engineered steel warehouse. The methodology followed is described below:

1. A three-dimensional analytical model of the industrial warehouse was first developed in STAAD.Pro CONNECT Edition uses the project geometry, bay spacing, roof slope, support conditions, and material properties. Structural loading was assigned in accordance with IS 875 (Part 1): 1987 for dead loads, IS 875 (Part 2):1987 for imposed (live) loads, IS 875 (Part 3):2015 for wind loads, and IS 1893 (Part 1):2016 for seismic loads. Appropriate load combinations were generated in accordance with the relevant code provisions, and structural analysis was carried out to determine member forces, bending moments, shear forces, support reactions, and nodal displacements. The steel members were subsequently designed in accordance with ANSI/AISC 360-16 (ASD). The adopted design approach combines Indian loading standards with the AISC steel design specification to reflect engineering practice commonly followed in industrial steel building projects involving international detailing and fabrication workflows.

2. After completion of the structural design, the finalized member sections were transferred to Tekla Structures 2024 to develop a detailed three-dimensional fabrication model. The model incorporated primary framing members, secondary framing members, roof and wall bracing systems, purlins, girts, base plates, connection plates, bolts, foundation bolts, roof and wall cladding components, and other fabrication accessories required for manufacturing and erection. This stage ensured that the analytical model was accurately transformed into a coordinated fabrication-ready Tekla Structures model, enabling efficient detailing and documentation throughout the fabrication process.

3. Fabrication drawings, assembly drawings, and erection drawings were generated directly from the developed Tekla Structures model. The coordinated digital model ensured consistency between structural design and fabrication documentation while minimizing manual modifications during the detailing process. These drawings provided complete fabrication and erection information required for manufacturing and on-site installation.

4. A comprehensive BOQ was extracted directly from the Tekla Structures model. The quantity report included primary structural members, secondary framing members, connection plates, bolts, foundation bolts, bracing components, roof and wall cladding systems, fasteners, and other miscellaneous fabrication accessories. To evaluate the effectiveness of the integrated digital workflow, the extracted quantities were compared with quantities obtained using a conventional manual estimation procedure.

5. The conventional quantity estimation was prepared from the approved two-dimensional structural drawings using standard engineering quantity take-off procedures. Individual member quantities were calculated from member lengths, section properties, and standard unit weights, while quantities for secondary members and miscellaneous components were obtained through manual measurement from fabrication drawings. Unlike the Tekla Structures-based automated quantity extraction, manual estimation involved greater dependence on engineering judgement and did not comprehensively capture connection components, fasteners, foundation bolts, and other fabrication accessories, resulting in differences between the two estimation methods.

6. The adopted methodology establishes a continuous digital workflow linking structural analysis, Tekla Structures-based detailing, fabrication documentation, and automated quantity estimation within a single coordinated engineering environment. The workflow improves information consistency between structural analysis and detailing, minimizes manual data transfer, and enhances the completeness of engineering documentation and quantity estimation. Although integrated digital workflows are widely recognized for improving project coordination, the present investigation focuses on documentation quality and quantity estimation rather than quantifying project cost savings or reductions in execution time, which remain beyond the scope of this study. The integrated digital engineering workflow adopted in this investigation is illustrated in Figure *2*.

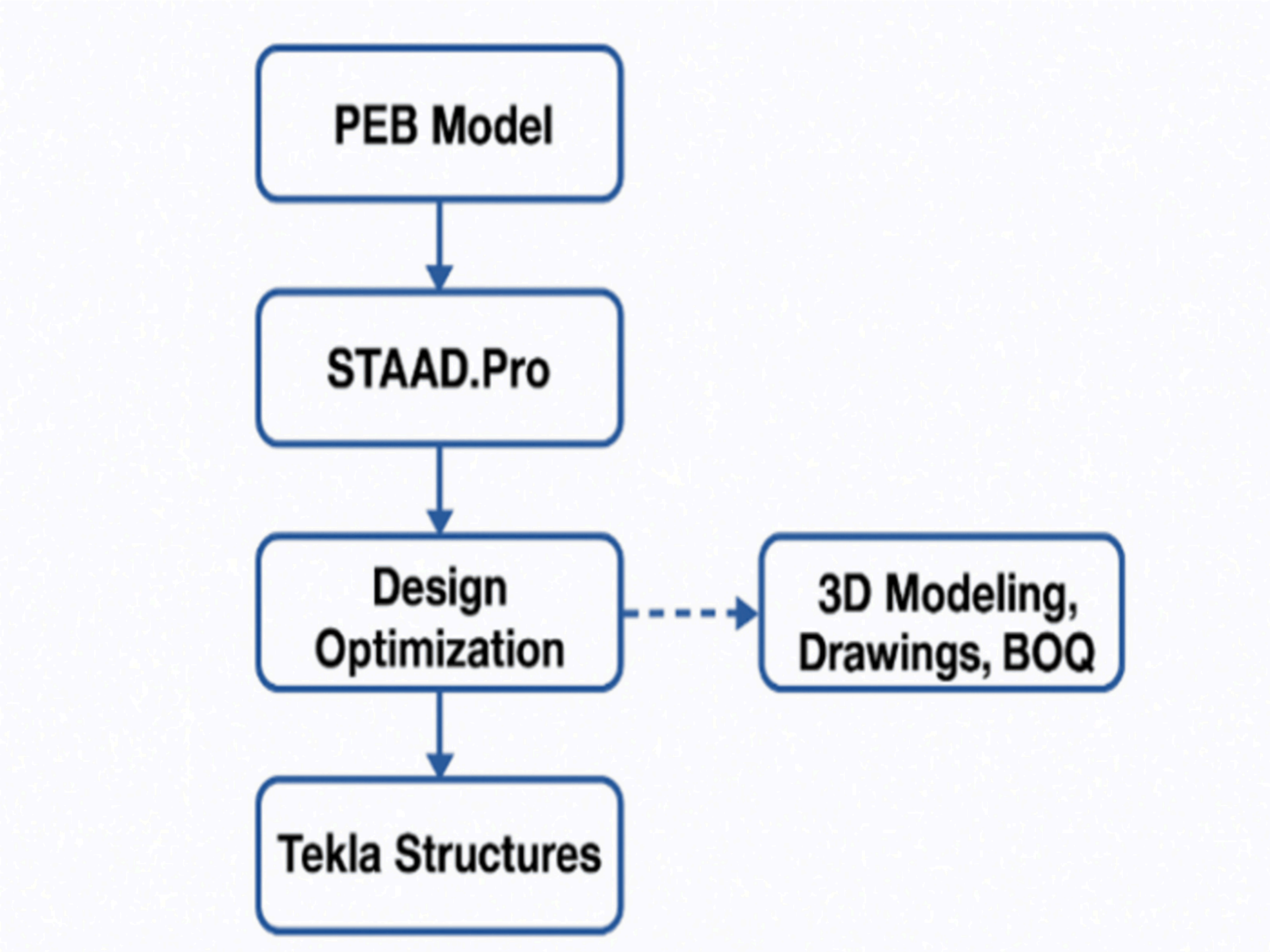

FIGURE 2: Presents the integrated workflow adopted in this investigation for structural analysis, detailing, and quantity estimation

Structure configuration

The proposed industrial steel warehouse has an overall plan measuring 23.40 m in length and 9.40 m in width, with an eave height of 5.50 m. The structural framing consists of six transverse portal frames, creating five center-to-center bay spacings of 3650 mm, 3900 mm, 3800 mm, 3850 mm, and 3950 mm, resulting in an overall building length of 23.40 m. This framing arrangement was selected to provide efficient load distribution while satisfying the functional requirements of an industrial warehouse. The roof was designed with a uniform slope of 1:10, which was consistently adopted in both the analytical model and the fabrication model. Column bases were modeled as pinned supports, representing the commonly adopted support condition for pre-engineered steel buildings, where base connections primarily transfer axial forces and shear while allowing rotational flexibility, thereby providing a realistic representation of practical industrial construction.

Plan and Elevation of the PEB Building

The plan, elevation, and sectional views illustrate the overall structural configuration adopted for the industrial warehouse. These drawings present the bay arrangement, framing layout, roof profile, column locations, principal dimensions, and coordinate references used for structural modeling and detailing. The figures provide a clear representation of the geometry considered during structural analysis and the subsequent development of the fabrication-level Tekla Structures model. The transverse elevation of the industrial warehouse is presented in Figure 3.

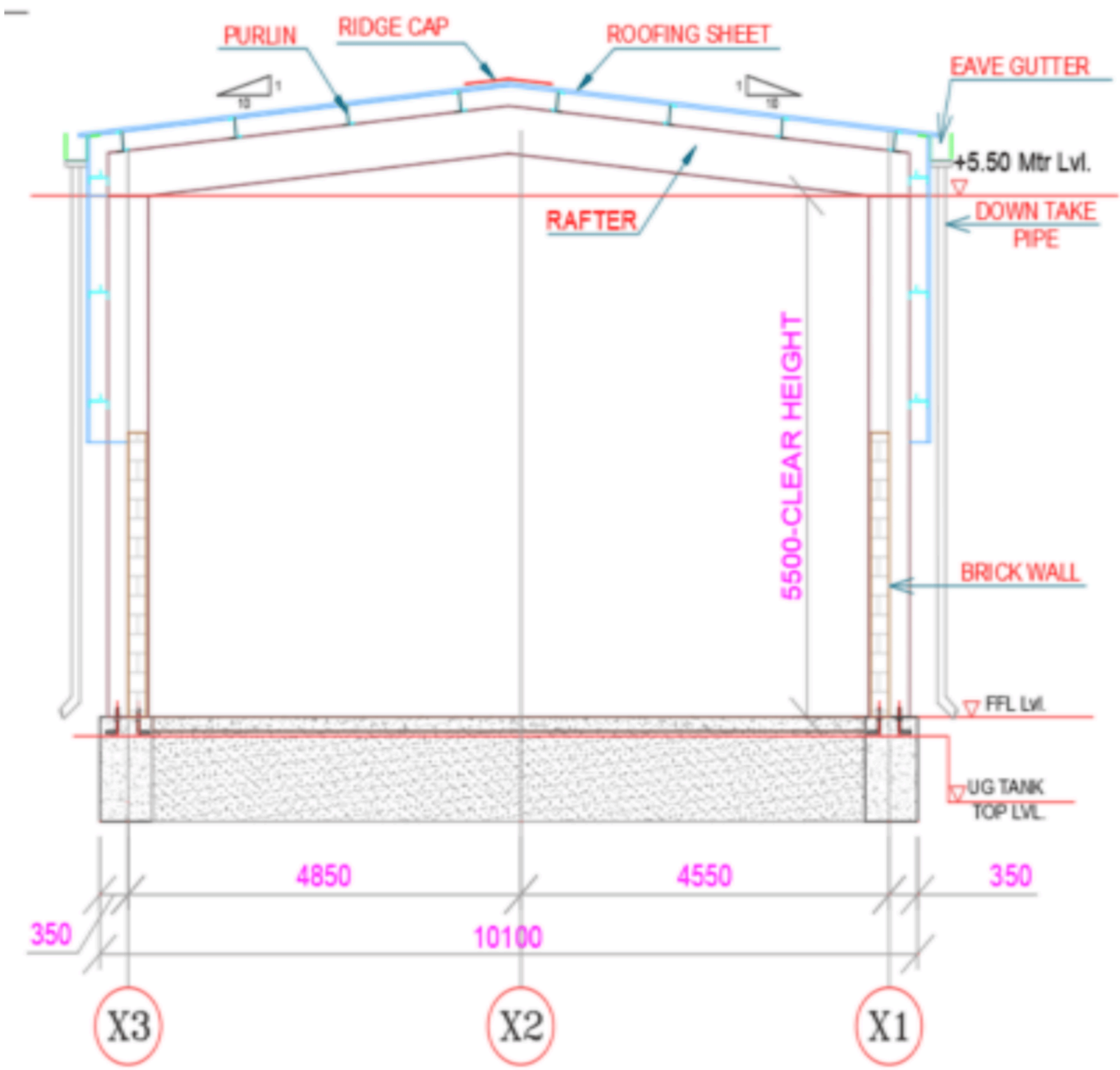

FIGURE 3: Transverse elevation of the industrial warehouse roof slope (1:10), column arrangement, and principal geometric dimensions

The structural framing layout adopted for the industrial warehouse is shown in Figure 4.

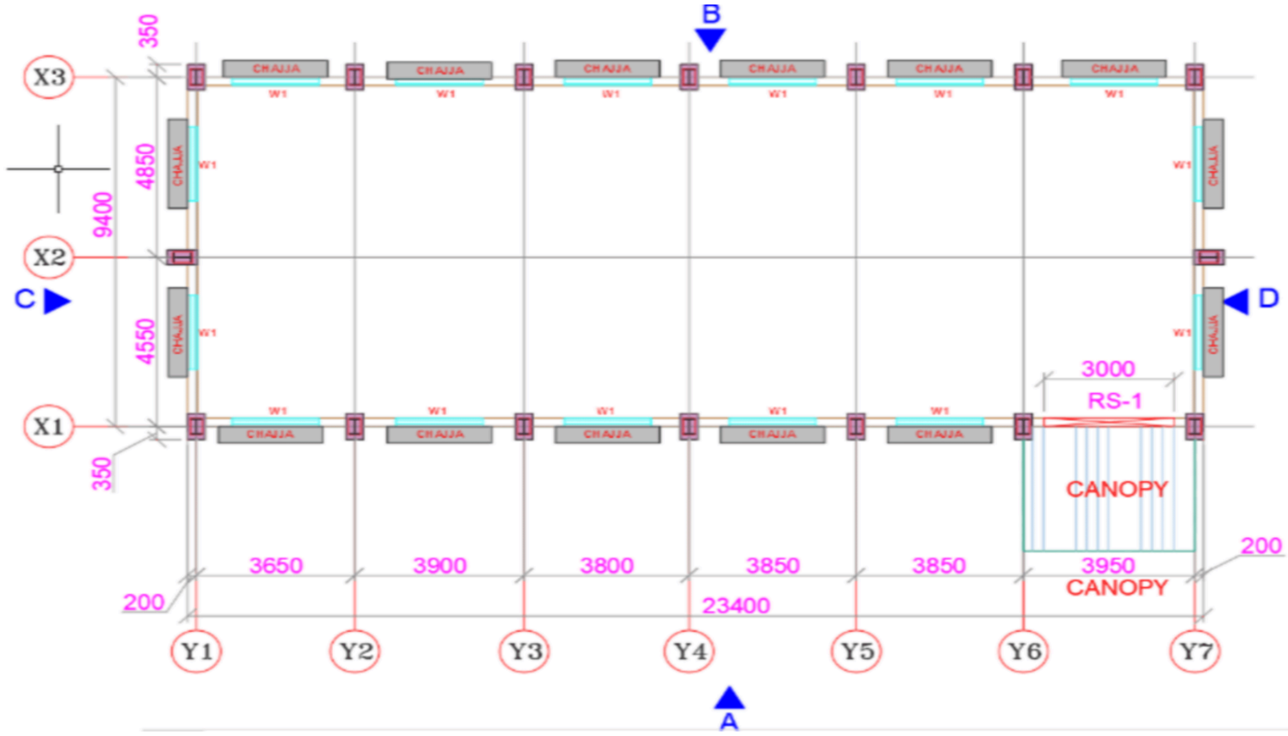

FIGURE 4: Structural plan illustrating the framing layout

Project Data and Structural Parameters

The structural analysis and design of the selected industrial pre-engineered steel warehouse were carried out using predefined geometric dimensions, material properties, design criteria, and site-specific loading conditions in STAAD.Pro CONNECT Edition. These input parameters formed the basis for developing the analytical model, assigning dead, live, wind, and seismic loads in accordance with the applicable design standards, selecting structural members, and evaluating the structural performance under the prescribed load combinations. The principal project specifications and design parameters adopted in the present investigation are summarized in Table 1.

S. No.	Details	Value
1	Location	High Seismic Zone
2	Number of Portal Frames	6
3	Total Building Length	23.40 m (c/c)
4	Bay Spacing (c/c)	3650 mm, 3900 mm, 3800 mm, 3850 mm, 3950 mm
5	Building Width	9.40 m (c/c)
6	Basic Wind Speed	39 m/s
7	Clear Height	5.50 m
8	Roof Slope	01:10
9	Support Condition	Pinned Column Base

TABLE 1: Geometric dimensions, structural configuration, and design parameters adopted for the warehouse

Results And Discussion

Structural analysis results

The industrial warehouse structure was analyzed using STAAD.Pro CONNECT Edition under the combined action of dead load, live load, wind load, and seismic load combinations in accordance with IS 875 (Parts 1-3):2015 and IS 1893 (Part 1):2016. The structural response was evaluated in terms of displacement, internal force distribution, bending moments, stress distribution, and overall structural stability.

The maximum vertical displacement observed in the structure was 37.773 mm, occurring near the mid-span region of the rafter under the governing service load combination. The allowable deflection limit for the adopted span was calculated as L/180 = 53 mm according to standard steel design practice. Since the calculated displacement remained significantly below the permissible limit, the structure satisfies the prescribed serviceability requirements and demonstrates adequate stiffness for industrial applications. The relatively low displacement can be attributed to the efficient portal frame configuration, appropriate member sizing, and the contribution of the roof and wall bracing systems, which collectively enhance the overall structural rigidity.

The maximum axial force developed in the primary columns was 201.736 kN, indicating that the adopted built-up column sections possess sufficient axial load-carrying capacity under the governing load combinations. The observed force distribution confirms that gravity and lateral loads are effectively transferred through the primary framing system to the foundations, demonstrating the structural adequacy and stability of the selected framing arrangement.

The highest bending moment recorded was 11.785 kN·m at the beam-column connection region. This behavior is consistent with the response of rigid portal frame systems, where beam-column joints experience significant moment transfer under combined gravity and lateral loading. The result highlights the importance of accurate connection detailing and fabrication to ensure satisfactory structural performance during service.

The maximum combined stress obtained from the STAAD.Pro design verification was 63.5 MPa, which remained well below the allowable design stress limits specified by ANSI/AISC 360-16 (ASD). Consequently, all primary and secondary structural members satisfied the prescribed strength requirements under the governing load combinations. The relatively low stress level indicates that the selected member sections provide an adequate margin of structural safety while maintaining satisfactory serviceability performance.

Overall, the structural analysis confirms that the proposed industrial steel warehouse satisfies the prescribed strength, stability, and serviceability requirements under the governing loading conditions. These findings are consistent with previous studies on pre-engineered steel buildings, which have reported that appropriately designed portal frame systems provide efficient load transfer, satisfactory structural performance, and reliable behavior under combined gravity, wind, and seismic loading conditions [9-11].

Structural stability assessment

The structural stability of the industrial steel warehouse was evaluated by examining the behavior of the primary framing system under the combined action of gravity, wind, and seismic loading. The adopted roof and wall cross-bracing systems contributed significantly to the lateral stability of the structure by enhancing the overall stiffness and providing efficient load paths for transferring lateral forces to the foundations. These bracing members effectively restrained excessive lateral displacement and improved the global stability of the portal frame system.

Among the prescribed loading conditions, wind loading governed the lateral structural response, which is consistent with the behavior of lightweight industrial steel buildings possessing relatively low seismic mass. The combined action of roof bracing, wall bracing, purlins, girts, and rigid portal frames ensured efficient distribution of lateral loads throughout the structural system, thereby reducing localized deformation and enhancing the overall structural performance.

The calculated seismic base shear was 4.71 kN, determined in accordance with IS 1893 (Part 1):2016. Although the project site was considered to be located in a high seismic zone, the relatively low seismic demand can be attributed to the lightweight steel framing system, moderate building dimensions, and efficient structural configuration, which collectively reduce the overall seismic mass and the corresponding earthquake-induced forces. Consequently, wind loading governed the structural design of the investigated warehouse rather than seismic loading.

The observed structural behavior demonstrates that the adopted framing configuration provides adequate lateral strength and stiffness while maintaining satisfactory stability under all prescribed loading combinations. These findings are consistent with previous studies on pre-engineered steel buildings, which have reported that lightweight portal frame systems with appropriately designed bracing arrangements provide efficient lateral load resistance, improved structural stability, and satisfactory performance under combined wind and seismic loading conditions [9-11]. Therefore, the adopted structural configuration is considered suitable for industrial steel warehouse applications under the specified loading conditions.

Evaluation of the integrated STAAD.Pro-Tekla Workflow

One of the principal objectives of the present investigation was to evaluate the effectiveness of integrating STAAD.Pro CONNECT Edition with Tekla Structures 2024 within a unified digital engineering workflow for structural analysis, detailing, fabrication documentation, and quantity estimation of an industrial steel warehouse. The integrated workflow enabled a continuous transfer of engineering information from structural analysis to the detailed Tekla Structures model, thereby minimizing manual data re-entry and improving consistency between the analytical and detailing models.

The performance of the proposed workflow was assessed by comparing conventional engineering practice with the integrated digital workflow, as presented in Table *2*.

Parameter	Conventional Practice	Integrated Digital Workflow
Structural Analysis	Performed independently	Integrated with Tekla Structures workflow
Design Updates	Manual coordination	Automatic model synchronization
BOQ Preparation	Manual quantity take-off	Automated quantity extraction
Drawing Generation	Semi-manual	Automated from the Tekla Structures model
Data Transfer	Manual	Digital model-based transfer
Coordination Errors	Higher possibility	Significantly reduced

TABLE 2: Comparison between the conventional engineering workflow and the integrated STAAD.Pro-Tekla structures workflow

The integration of structural analysis with Tekla Structures substantially improved information consistency throughout the design process by eliminating repeated manual data transfer between software platforms. The coordinated digital workflow enabled automatic generation of fabrication drawings, assembly drawings, erection drawings, and material quantity reports directly from the developed Tekla Structures model, thereby ensuring consistency between structural design and fabrication documentation. In addition, automated quantity extraction reduced the likelihood of omissions associated with conventional manual quantity take-off, particularly for secondary structural members, connection components, fasteners, foundation bolts, and other fabrication accessories.

Unlike conventional workflows, where revisions to structural members often require repeated manual updates to fabrication drawings and quantity schedules, the integrated workflow maintained consistency across analytical, detailing, and documentation stages through a single coordinated Tekla Structures model. This improved the traceability of engineering information and enhanced documentation quality, thereby facilitating communication among structural engineers, detailers, fabricators, and project stakeholders.

The findings of the present study are consistent with previous investigations reporting that integrated digital workflows improve project coordination, documentation accuracy, and model-based quantity estimation by linking structural design with fabrication-level detailing [9-13]. However, unlike earlier studies that primarily evaluated structural analysis or detailing software independently, the present investigation demonstrates a complete structural design-to-fabrication workflow supported by a quantitative comparison with conventional manual quantity estimation. It should be noted that the present study evaluates improvements in documentation quality and quantity estimation only; a quantitative assessment of project cost savings and reductions in execution time was beyond the scope of the investigation because fabrication and construction-stage performance data were not available.

BOQ analysis

A comprehensive BOQ was generated directly from the developed Tekla Structures model, incorporating primary structural members, secondary framing members, connection components, fasteners, foundation bolts, roof sheeting, wall cladding, and other fabrication accessories. The automated quantity extraction ensured that all structural and fabrication elements were included in a single coordinated quantity report. The distribution of structural quantities extracted from the Tekla Structures model is presented in Table 3.

Component	Weight (kg)
Primary Structure	6232
Secondary Structure	3589.92
Fasteners	240
Foundation Bolts	136
Roof Sheeting, Cladding & Accessories	2463
Total	12960.9

TABLE 3: Distribution of structural quantities extracted from the Tekla Structures model

The quantity analysis indicated that the primary structural framing contributed 6,232 kg, representing approximately 48.1% of the total project weight. Secondary structural members accounted for 3,589.92 kg (27.7%), while roof sheeting, wall cladding, and accessories contributed 2,463 kg (19.0%). Fasteners and foundation bolt assemblies contributed 240 kg and 136 kg, respectively. The total estimated structural quantity obtained from the Tekla Structures model was 12,960.92 kg (12.97 metric tons).

The results demonstrate that a substantial proportion of the total project weight originates from secondary framing members and fabrication accessories rather than the primary structural system alone. Consequently, omission or simplification of these components during conventional manual quantity estimation may result in underestimation of material requirements, affecting procurement planning and fabrication scheduling.

Validation of quantity estimation

To evaluate the reliability of the proposed workflow, the quantities extracted from the Tekla Structures model were compared with those obtained using conventional manual quantity estimation based on two-dimensional structural drawings. A comparison between conventional manual quantity estimation and automated quantity extraction using Tekla Structures is presented in Table 4.

Component	Manual Estimation (kg)	Tekla Structures (kg)	Difference (kg)	Difference (%)
Primary Structure	6100	6232	132	2.16
Secondary Structure	3520	3589.9	69.92	1.99
Fasteners	0.00*	240	240	—
Foundation Bolts	0.00*	136	136	—
Roof Sheeting, Cladding & Accessories	2310	2463	153	6.62
Total	11930	12961	1030.9	8.64

TABLE 4: Comparison between conventional manual estimation and Tekla Structures quantity extraction

The quantitative comparison demonstrates that the integrated digital workflow produced a total estimated structural quantity of 12,960.92 kg, whereas the conventional manual estimation resulted in 11,930 kg, representing an increase of 1,030.92 kg (8.64%). The additional quantities were primarily attributed to the inclusion of connection components, fasteners, foundation bolts, and other fabrication accessories that were either simplified or omitted during conventional quantity take-off. These findings indicate that automated quantity extraction from the Tekla Structures model provides a more comprehensive representation of the actual fabrication requirements and improves the reliability of material estimation for procurement and fabrication planning.

Comparison with published literature

The findings of the present investigation are consistent with previous studies demonstrating that integrated digital engineering workflows improve documentation quality, engineering coordination, and quantity estimation. Similar studies have reported that model-based quantity extraction provides more comprehensive material estimation than conventional manual quantity take-off by accurately capturing secondary structural members, connection components, and fabrication accessories [9-13].

In the present study, the integrated workflow produced a total estimated structural quantity of 12,960.92 kg, compared with 11,930 kg obtained through conventional manual estimation, representing an increase of 8.64%. This increase resulted primarily from the inclusion of secondary framing members, connection components, foundation bolts, fasteners, and cladding systems that are frequently underestimated in traditional estimation procedures.

Unlike previous investigations that mainly evaluated structural optimization or individual software applications, the present study demonstrates a complete engineering workflow integrating structural analysis, detailing, fabrication documentation, and automated quantity estimation within a single coordinated digital environment. Although the investigation is limited to a single industrial warehouse, it provides practical evidence supporting the application of integrated digital workflows in industrial steel construction projects.

How to cite this article:
Singh B, Rodwal V, Rajput P (August 20, 2026) Integrated Digital Workflow for Structural Design, Fabrication Documentation, and Quantity Estimation of an Industrial Steel Warehouse. Cureus J Eng 3 : es44388-026-00232-1. DOI https://doi.org/10.7759/s44388-026-00232-1

Conclusions

The present study demonstrated the successful implementation of an integrated digital engineering workflow combining STAAD.Pro CONNECT Edition and Tekla Structures 2024 for the structural analysis, detailing, fabrication documentation, and quantity estimation of an industrial steel warehouse. The structural analysis confirmed that the proposed warehouse satisfied the prescribed strength, stability, and serviceability requirements under the governing dead, live, wind, and seismic loading conditions. The subsequent development of the detailed Tekla Structures model enabled the automatic generation of fabrication drawings, assembly drawings, erection drawings, and comprehensive material quantity reports from a single coordinated digital model.

The quantitative comparison between conventional manual estimation and automated quantity extraction demonstrated that the integrated workflow produced a total estimated material quantity of 12,960.92 kg, compared with 11,930 kg obtained using conventional estimation, representing an increase of 1,030.92 kg (8.64%). This difference primarily resulted from the inclusion of secondary structural members, connection components, foundation bolts, fasteners, roof sheeting, wall cladding, and other fabrication accessories that are frequently simplified or omitted during conventional quantity take-off. These findings demonstrate that model-based quantity extraction provides a more comprehensive representation of actual fabrication requirements and improves the reliability of engineering documentation for procurement and fabrication planning.

The principal scientific contribution of this study is the demonstration of a complete structural design-to-fabrication workflow, integrating structural analysis, detailing, fabrication documentation, and automated quantity estimation within a single coordinated digital environment. Unlike studies that evaluate structural analysis or detailing software independently, the proposed methodology demonstrates the practical integration of both platforms using an industrial warehouse case study and provides quantitative evidence of the benefits of digital engineering workflows for improving documentation completeness and quantity transparency.

Although the investigation was limited to a single industrial warehouse, the proposed methodology provides a practical and reproducible framework for industrial steel construction projects. Future research should validate the workflow using multiple building configurations and evaluate its application in fabrication planning, project cost estimation, construction scheduling, and digital project delivery to further establish its broader engineering applicability.

Additional Information

Author Contributions

All authors have reviewed the final version to be published and agreed to be accountable for all aspects of the work.

Concept and design: Brajendra Singh

Drafting of the manuscript: Brajendra Singh

Critical review of the manuscript for important intellectual content: Brajendra Singh, Vasudev Rodwal, Priyanka Rajput

Acquisition, analysis, or interpretation of data: Vasudev Rodwal, Priyanka Rajput

Supervision: Vasudev Rodwal, Priyanka Rajput

Disclosures

Human subjects: All authors have confirmed that this study did not involve human participants or tissue. **Animal subjects:** All authors have confirmed that this study did not involve animal subjects or tissue. **Conflicts of interest:** In compliance with the ICMJE uniform disclosure form, all authors declare the following: **Payment/services info:** All authors have declared that no financial support was received from any organization for the submitted work. **Financial**

How to cite this article:
Singh B, Rodwal V, Rajput P (August 20, 2026) Integrated Digital Workflow for Structural Design, Fabrication Documentation, and Quantity Estimation of an Industrial Steel Warehouse. Cureus J Eng 3 : es44388-026-00232-1. DOI https://doi.org/10.7759/s44388-026-00232-1

relationships: All authors have declared that they have no financial relationships at present or within the previous three years with any organizations that might have an interest in the submitted work. **Other relationships:** All authors have declared that there are no other relationships or activities that could appear to have influenced the submitted work.

Data Availability Statements

The datasets (and/or code) supporting this study are available from the corresponding author upon reasonable request. Artificial intelligence-assisted language editing (ChatGPT, OpenAI) was used solely to improve grammar, sentence structure, and language clarity during manuscript preparation. All structural modeling, engineering calculations, software analysis, interpretation of results, and scientific conclusions were independently performed and verified by the authors.

References

1. Bureau of Indian Standards: IS 800:2007 - General Construction in Steel - Code of Practice. (2007). Accessed: June 28, 2026: https://www.services.bis.gov.in.
2. Bureau of Indian Standards: IS 875 (Part 1):1987 - Code of Practice for Design Loads (Dead Loads). (1987). Accessed: June 28, 2026: https://www.services.bis.gov.in.
3. Bureau of Indian Standards: IS 875 (Part 2):1987 - Code of Practice for Design Loads (Imposed Loads). (1987). Accessed: June 28, 2026: https://www.services.bis.gov.in.
4. Bureau of Indian Standards: IS 875 (Part 3):2015 - Design Loads (Wind Loads). (2015). Accessed: June 28, 2026: https://www.services.bis.gov.in.
5. Bureau of Indian Standards: IS 1893 (Part 1):2016 - Criteria for Earthquake Resistant Design of Structures. (2016). Accessed: June 28, 2026: https://www.services.bis.gov.in.
6. American Institute of Steel Construction: Specification for Structural Steel Buildings (ANSI/AISC 360-16). (2016). Accessed: June 28, 2026: https://www.aisc.org/specifications.
7. Subramanian N: Design of Steel Structures. Oxford University Press. 2019, https://global.oup.com.
8. Duggal SK: Limit State Design of Steel Structures. McGraw Hill Education. 2018, https://www.mheducation.co.in.
9. Sacks R, Eastman C, Lee G, Teicholz P: BIM Handbook: A Guide to Building Information Modeling for Owners, Designers, Engineers, Contractors, and Facility Managers. John Wiley & Sons, Inc., 2018. 10.1002/9781119287568
10. Erliafina E, Lusiana L, Syahrudin S: Implementation of Building Information Modeling (BIM) Utilizing Tekla Structures for Work Volume Calculation (Institute of Technology Keling Kumang Project in Sekadau District). Jurnal Teknik Sipil Edisi. 2024, 24:1480-1492. 10.26418/jts.v24i4.86835
11. Doubi Y, Hartiti B, Hicham L, et al.: Effect of annealing time on structural and optical proprieties of TiO2 thin films elaborated by spray pyrolysis technique for future gas sensor application. Materials Today: Proceedings. 2020, 30:823-827. 10.1016/j.matpr.2020.04.186
12. Trimble Solutions Corporation: Tekla Structures Documentation. (2024). Accessed: June 28, 2026: https://support.tekla.com/documentation.
13. Bentley Systems Inc.: STAAD.Pro CONNECT Edition Technical Reference Manual. (2024). Accessed: June 28, 2026: https://docs.bentley.com.

How to cite this article:
Singh B, Rodwal V, Rajput P (August 20, 2026) Integrated Digital Workflow for Structural Design, Fabrication Documentation, and Quantity Estimation of an Industrial Steel Warehouse. Cureus J Eng 3 : es44388-026-00232-1. DOI https://doi.org/10.7759/s44388-026-00232-1