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Optimization of Tekla Structures Based Design Solutions for Retrofitting and Rehabilitation of Steel Structures / (Bim-Based Optimization of Steel Structure Retrofitting and Rehabilitation using Tekla Structures)

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ABSTRACT: The optimization process is achieved through iterative design modifications and simulations, considering factors such as material properties, load conditions, and safety standards. By leveraging Tekla Structures' parametric modelling capabilities and integrated analysis tools, this research explores innovative design solutions that enhance structural integrity, reduce maintenance costs, and minimize environmental impact.

The rehabilitation and retrofitting of steel structures are paramount in the field of structural engineering, ensuring the longevity and safety of existing infrastructure. This study focuses on the application of advanced computer-aided design (CAD) software, specifically Tekla Structures, to optimize design solutions for retrofitting and rehabilitating steel structures.

The results of this study showcase the effectiveness of Tekla Structures in streamlining the retrofitting and rehabilitation process, leading to structurally sound and economically viable solutions. The optimized designs demonstrate improved load-bearing capacity, enhanced resilience against natural disasters, and increased sustainability through the incorporation of modern materials and construction techniques.

KEYWORDS: Computer-aided design, Tekla, Steel structures, sustainability Rehabilitation, Retrofitting, Software.

I. INTRODUCTION

The increasing demand for sustainable infrastructure has led to a growing emphasis on the retrofitting and rehabilitation of existing steel structures instead of complete replacement. Steel structures are widely used in industrial buildings, commercial complexes, bridges, warehouses, and high-rise buildings due to their high strength-to-weight ratio, durability, and ease of construction. However, over time, these structures may experience deterioration caused by corrosion, fatigue, excessive loading, seismic events, environmental exposure, design deficiencies, or changes in functional requirements. To ensure structural safety, extend service life, and reduce maintenance costs, effective retrofitting and rehabilitation strategies have become essential.

Steel structures are a fundamental part of modern infrastructure, playing a pivotal role in supporting buildings, bridges, industrial facilities, and various other critical components of our built environment. Over time, these structures may encounter various challenges, such as deterioration, increased load requirements, or changes in design codes and standards. To ensure the continued safety, functionality, and sustainability of steel structures, retrofitting and rehabilitation measures become imperative.

Optimization plays a crucial role in selecting the most efficient retrofitting solution. By integrating BIM-based modelin, with structural engineering principles, various strengthening alternatives—such as adding steel plates, bracing systems, stiffeners, member replacement

1.1 Importance of Retrofitting of Steel Structures

a) What is Retrofitting?

Retrofitting in structural engineering refers to the process of modifying, strengthening, or upgrading existing buildings or structures to improve their performance, safety, functionality, or sustainability. Retrofitting is the process of strengthening or upgrading an existing structure to improve its structural performance, safety, and load-carrying capacity beyond its original design. It is typically carried out to meet updated design codes, resist increased loads, or improve resistance against earthquakes, wind, fire, or other hazards. Here are some common reasons for retrofitting in structural engineering:

Here are some common reasons for retrofitting in structural engineering:

- Safety Improvement
- Structural Integrity
- Load Capacity Enhancement
- Energy Efficiency

1.2 Importance of Rehabilitation of Steel Structures

a) What is Rehabilitation of Steel Structures?

Rehabilitation of steel structures is a process that involves the repair, restoration, or refurbishment of existing steel buildings or structures to extend their service life, improve their performance, and address structural deficiencies or degradation. The goal of rehabilitation is to ensure that these structures continue to meet safety standards, function effectively, and remain sustainable while minimizing the need for new construction.

Here are some key aspects of rehabilitation of steel structures:

Repair and Maintenance, Strengthening, Corrosion Protection, Seismic Retrofitting, Upgrading for New Uses, Upgrading for New Uses, Historic Preservation, Energy Efficiency, Compliance with Codes and Standards.

Rehabilitation is the process of repairing, restoring, and improving an existing structure that has deteriorated or been damaged due to aging, corrosion, fatigue, environmental effects, overloading, or natural disasters. The primary objective is to restore the structure to a safe and functional condition while extending its service life.

Rehabilitation may include:

- Repairing corroded steel members
- Replacing damaged structural components
- Treating corrosion and applying protective coatings
- Repairing cracks and defective connections
- Restoring the structural integrity of the building

Let's break down the research title "Optimization of Tekla Structures-Based Design Solutions for Retrofitting and Rehabilitation of Steel Structures" / "BIM-Based Optimization of Steel Structure Retrofitting and Rehabilitation Using Tekla Structures" into simpler terms:

1. **Optimization:** Optimization means finding the best or most efficient way to achieve a particular goal. In this research, optimization refers to the process of using Tekla Structures to improve or make the design of retrofitting and rehabilitating steel structures more efficient, cost-effective, and effective in meeting safety and performance standards.
2. **Tekla Structures-Based Design Solutions:** Tekla Structures is a sophisticated computer-aided design (CAD) and building information modelling (BIM) software used in the construction and engineering industry. It's used for creating detailed 3D models of structures and for designing various aspects of those structures, such as beams, columns, and connections. The research is going to use this software as a tool to develop design solutions.
3. **Retrofitting and Rehabilitation:** This part of the research focuses on existing steel structures that may be old, damaged, or no longer meet current safety or performance standards. Retrofitting and rehabilitation involve making improvements or changes to these structures to ensure they remain safe and functional.
4. **Steel Structures:** The research is specifically concerned with structures made primarily of steel, such as buildings, bridges, or industrial facilities. Steel is a common material in construction due to its strength and durability.

II. RESEARCH OBJECTIVES

The primary objectives of this study are as follows:

To develop an accurate 3D BIM model of an existing steel structure using Tekla Structures.

To assess the condition of the existing steel structure by identifying structural deficiencies, damaged members, and areas requiring retrofitting or rehabilitation

Seismic Resilience: To enhance the seismic resilience of steel structures, a critical consideration in regions prone to seismic activity

Sustainability: To consider sustainable practices and materials in the retrofitting and rehabilitation process, aligning with global sustainability goals.

Cost-Efficiency: To identify cost-effective methodologies within Tekla Structures that optimize resource allocation, balancing project quality with budget constraints.

2.1 Significance of the Study

The significance of this study is multi-faceted:

Innovation: The integration of advanced software tools like Tekla Structures represents an innovative approach to retrofitting and rehabilitation practices, keeping structural engineering at the forefront of industry advancements.

Sustainability: The research contributes to sustainability goals by extending the service life of existing structures and reducing the need for new construction, minimizing the environmental footprint.

- Provides a BIM-based approach for planning and designing retrofit solutions.
- Improves the accuracy of structural analysis and detailing.
- Assists in selecting efficient and economical strengthening methods.

III. METHODOLOGY

3.1 Software used for design & Details about project

Steel structure design in TDS 2023 (TDS: Tekla Structural Designer 2023) Table No 1: Software Detail-

Software	Version	Service pack	Environment	License
TDS	2023	14	USA	-

3.2 Tekla Structural Designer Steel - warehouse Details: our warehouse is G+2

Span (c/c): 30 m

Length (c/c): 20m Sectional Length (c/c): 2.667 m Eve Height: 4.2 m

Ridge Height: 5.2 m Mezzanine Floor: 3.2 m Unit-matric

3.3 Data Collection:

We have collect existing steel structure data by doing some test and we got following test data which we have mentioned in below table

Load Increment (KN)	Deflection (mm)	Load-Carrying Capacity (KN)
0	0	0
5	1.2	5
10	2.5	10
15	4.0	15
20	6.2	20
25	9.0	25
30	12.5	30

35	16.7	35
40	21.6	40
45	27.2	45
50	33.5	50

Failure Load 43.8 (ultimate load)

3.4 Test Objective: The objective of test is to assess the effectiveness of a retrofitting method in enhancing the load-carrying capacity and structural integrity of a steel beam.

General Stages in Structural Design Using Software tekla structural designer

Structural design using software like Tekla Structural Designer typically involves several general stages to ensure the safe and efficient performance of a structure. Below are the key stages in the structural design process using Tekla Structural Designer,

Step 1: Project Initiation

Project Initiation is the first stage in the structural design process, where the project's objectives, scope, requirements, and design criteria are established before creating the structural model in Tekla Structural Designer. Determine the design codes and standards that apply to the project.

Step 2: Structural Analysis

Create a digital model of the structure within Tekla Structural Designer. This includes defining the geometry, material properties, and loads (dead loads, live loads, wind loads, seismic loads, etc.) Perform structural analysis to calculate internal forces, stresses, and deflections.

Verify that the structure meets safety and performance criteria specified in design codes.

Step 3: Load Combinations

Generate load combinations as per the design codes to assess the structure's response under various loading scenarios (e.g., ultimate limit state, serviceability limit state).

Step 4: Design of Structural Elements

Design individual structural elements such as beams, columns, slabs, and foundations using Tekla Structural Designer's built-in design modules. Ensure that the elements meet the code requirements for strength, stiffness, and durability.

Iteratively refine the design as needed.

Step 5: Seismic Analysis and Design (if applicable)

If the project is located in a seismic zone, perform seismic analysis and design to ensure that the structure can withstand seismic forces. Implement seismic-resistant detailing and reinforcement as required by seismic design codes.

Step 6: Structural Optimization (optional)

Depending on project goals and constraints, consider structural optimization to minimize material usage, reduce costs, or improve performance. Tekla Structural Designer may have built-in optimization features or interfaces with other optimization software.

Step 7: Foundation Design

Design the foundation systems, including footings, piles, or mats, to ensure adequate support for the structure. Verify that the foundation design meets stability and settlement criteria.

Step 8: Structural Detailing

Generate detailed structural drawings, including plans, elevations, and sections. Produce reinforcement schedules and detailing for reinforced concrete elements. Export the drawings and schedules directly from Tekla Structural Designer or integrate with Tekla Structures for more advanced detailing.

Step 9: Documentation

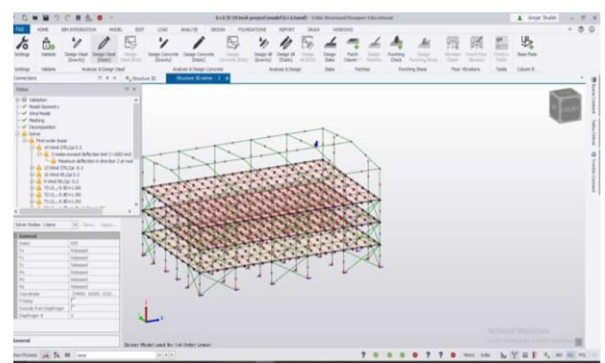
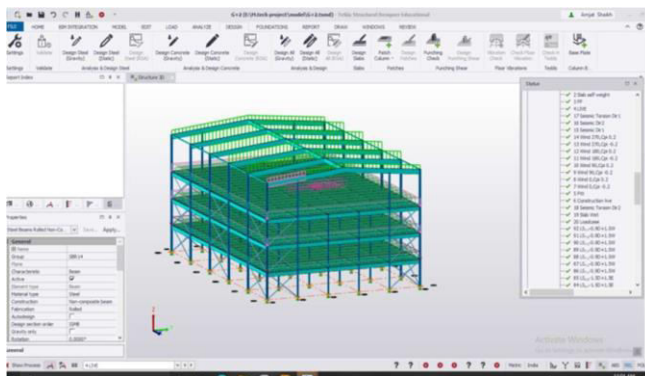
Compile design reports, calculations, and other documentation required for regulatory approvals and construction. Ensure that all documentation complies with industry standards and local building codes.

Step 10: Review and Validation

Conduct a thorough review of the design to verify its accuracy and compliance with design codes. Seek peer review or third-party validation if necessary.

Step 11: Construction Stage

- Using the model from the Detailed Design stage, much of the Construction Stage process will take place in Tekla Structures so that the integration with other trades can be accounted for.
- The design is not revisited unless the client drives the requirement for change.
- If a re-design of the structure is required, the same synchronization of Tekla Structural Designer and Tekla Structures models can be carried out to suit the user.
- The model will be completed within Tekla Structures and fully detailed drawings for parts can be created along with construction level drawings of the structure.
- Detail integration checks with other trades (e.g. Mechanical and Electrical Engineers) can be carried out at this stage.



Beam Group Design Summary

Reference	No. in Group	Critical Member	Static		Section	Grade	Max. UR	Status
			Spans	Critical Span				
SBR1	9	SB 3/F/4-3/F/5	1	1	MB 450	Fe 410	0.047	Pass
SBR3	10	SB 4/D/6-4/E/6	1	1	145.0x82.0x4.8	Fe 410	0.993	Pass
SBR4	3	SB 3/F/5-3/F/6	1	1	MB 450	Fe 410	0.131	Pass
SBR5	91	SB 5/E/#468-5/F/#471	1	1	MB 500	Fe 440	0.682	Pass
SBR6	4	5/D/#470	1	1	MB 500	Fe 440	0.682	Pass
SBR14	297	SB 1/5/#13-1/6/#14	1	1	MB 450	Fe 440	0.074	Pass
SBR15	6	SB 3/A/5-3/A/6	1	1	MB 450	Fe 440	0.177	Pass
SBR18	11	1/B/#1117	1	1	MB 600	Fe 440	0.892	Pass



IV. CONCLUSION

Steel buildings can be analysed and designed easily with Tekla Structural Designer. The paper has the details of the structural elements, material listing, design summary, load case summary with Tekla Structural Designer with country standards. It includes how building a steel building is a good option to choose to construct steel buildings and its efficiency to reduce time of construction, cost, maintenance, increased sustainability and durability, enhanced quality to assemble at site.

When we construct building in steel structure we can easily increase the life of structure after 59 | Page some decade With the help of tekla structural designer we can analyze existing structure and their load carrying capacity and behavior

of steel member.

The structural system of the warehouse is generally stable and safe. However, the failure of specific members under load conditions highlights the need for:

- └ Redesign or strengthening of failed column and brace members.
- └ Ensuring proper lateral and strut restraints to prevent instability or buckling.
- └ Further optimization and cross-verification to enhance structural performance and safety.

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