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A Comparison Between Software STAAD. Pro and Autodesk Structural Bridge Design for Swing Bridge

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Abstract

Bridges are critical for contemporary transportation, particularly in logistics involving cargo ships and railroads. This research focuses on developing a swing bridge that connects routes for both trains and cargo ships, solving the issue of operating delays caused by disagreements between the two types of transportation. The swing bridge design was evaluated using STAAD.Pro and Autodesk Structural Bridge Design software. The investigation involved estimating the forces on the cantilever structure and assessing the bridge under dead and live loads. The study concluded that the swing bridge is an excellent choice owing to its high degree of safety, which is the consequence of a strong design and a constantly monitored rotating mechanism. The comparison investigation demonstrated that both software tools give credible insights into member forces and joint displacements, although with minor variances due to differing analytical approaches. The swing bridge improves logistical operations by allowing safe transit for trains and cargo ships, making it a viable option for future infrastructure projects.

1. Introduction

Bentley Systems STAAD.Pro and Autodesk Structural Bridge Design (SBD) are two prominent software tools used in structural engineering. STAAD.Pro is renowned for its versatility and advanced features, such as dynamic analysis, finite element analysis, and extensive support for international design codes, making it ideal for projects involving towers, bridges, buildings, and other infrastructure. Its sophisticated modelling capabilities, user-friendly interface, and comprehensive material catalogue help engineers enhance designs for cost-effectiveness, utility, and safety.

In contrast, Autodesk Structural Bridge Design is tailored specifically for bridge engineering, integrating modelling, analysis, and load-rating capabilities into a single platform. It supports various international bridge design standards and offers sophisticated analytical tools, automatic load applications, and extensive reporting options, making it essential for efficient and effective bridge design.

This study aims to address the logistical challenges at ports where rail and water routes intersect by developing a swing bridge using both software tools to analyze its performance under dead and live loads.
The research will compare the capabilities of STAAD.Pro and Autodesk Structural Bridge Design, focusing on the design and analysis of a swing bridge at the Malaysia-Singapore border. It will assess the efficiency, usability, and integration potential of each software, aiming to improve traffic connectivity and logistics management in the region by identifying the best tool for future swing bridge projects. The expected outcome is a thorough

understanding of the strengths and limitations of each software, providing recommendations for optimizing swing bridge design and enhancing transportation infrastructure.

1.1 Software STAAD.Pro

Bentley Systems STAAD.Pro is a popular structural analysis and design software that is widely used in infrastructure projects such as towers, bridges, and buildings [1]. It supports international design codes and offers a full range of modelling, analysis, and design capabilities, including finite element analysis, dynamic analysis, and load combination capabilities [2]. STAAD.Pro is the most widely used software program for creating, analyzing, and designing multi-material 3D models. It features strong analysis and design capabilities, easy-to-use visualization tools, and seamless interaction with other modelling and design software packages [3].

1.2 Autodesk Structural Bridge Design

Autodesk Structural Bridge Design is a software that streamlines bridge engineering by combining load-rating, analysis, and modelling skills [4]. It offers reporting options, automatic load applications, sophisticated analytical capabilities, and supports international design standards [5].

1.3 Pratt Truss Bridge

A Pratt truss bridge is a structural design commonly used for railway bridges, featuring vertical and diagonal members with the diagonal inclined towards the middle. This design is simple, economical, and easy to construct due to its simple, economical design and ease of construction [6]. It is suitable for large loads and is strong and reasonably priced due to its diagonal layout. Recent research focuses on enhancing the redundancy of these bridges to improve their stability [7].

1.4 Warren Truss Bridge

The Warren truss bridge is a lightweight, robust, and cost-effective truss design with equilateral triangles [6]. Its lightweight design distributes tension and compression stresses, making it suitable for larger spans. Equilateral triangles minimize forces and enhance structural efficiency, making it ideal for pedestrian and light vehicle bridges. The bridge's dynamic response to different loading scenarios demonstrates its robustness and longevity [7].

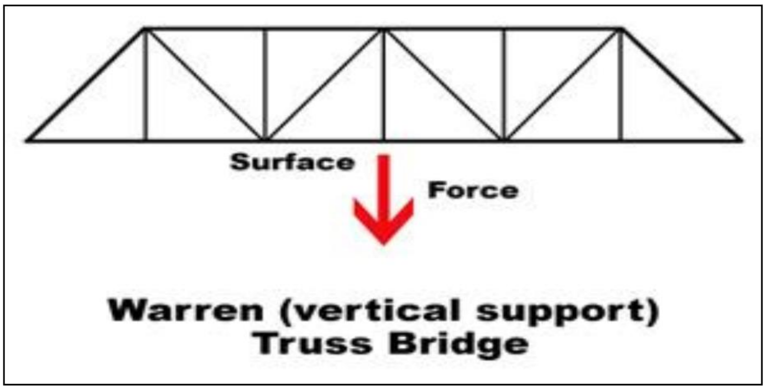

Fig. 1 *Warren Truss Bridge*

1.5 Swing Bridge Design

A swing bridge consists of two balanced spans, a steel grid, and steel sails. It has a 13-meter deck and a 13-meter width [8]. Traffic loads are supported by cross beams, girders, and a V-shaped strut. The bridge has a hydraulic lift/turn cylinder for torque transmission and structural lowering. A hydraulic lift/turn cylinder and wedge-shaped end locks maintain rail continuity [9]. Simulation software like STAAD.Pro and Autodesk Structural Bridge Design improve safety and performance. Advanced materials like high-strength steel and composites reduce weight while maintaining strength.

1.6 Material of the Bridge

Steel is crucial in bridge construction due to its strength, ductility, and structural versatility. Recent advancements in steel materials have led to the use of high-strength steel (HSS) and high-performance steels (HPS). HSS offers improved load-bearing capacity and lower material consumption, resulting in lighter bridge constructions and cost savings. HPS improves bridge safety by offering improved toughness, ductility, and strength, reducing earthquake susceptibility. Although initially more expensive, HPS can save money over time by reducing rebuilding and maintenance costs [10].

1.7 Rotation Method

The rotating method, a new approach to bridge construction, has gained popularity due to its quick, inexpensive, and minimal impact on traffic [11]. The swing bridge uses two rotating systems installed on opposite sides of the terrain, rotating to the bridge axis when necessary. This method is particularly useful in areas with mountains, congested traffic, and limited space [11]. However, rotation is susceptible to damage, and the swing process is crucial for the bridge's stability. The increasing frequency of traffic line crossings will impact existing lines, particularly bridge crossings over traffic lines [12].

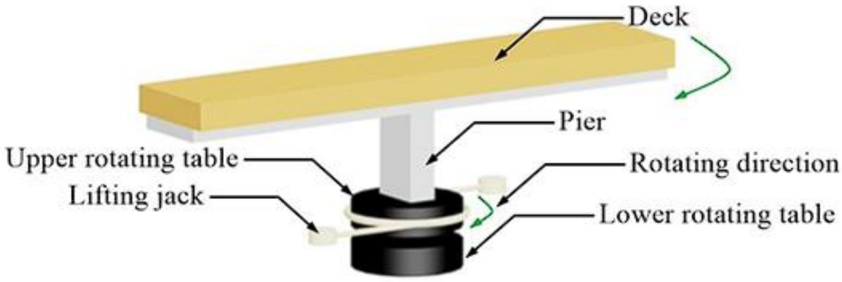

Fig. 2 *Rotating system and rotating process*

2. Methodology

2.1 Conceptual Design of Swing Bridge

The proposed Pratt and Warren Truss swing bridge is designed for train and railway traffic, with dimensions of 15 meters wide, 5 meters tall, and 90 meters long. This design is ideal for difficult environments due to its efficient load distribution and simplicity of construction. The Pratt truss, with diagonal members under tension and vertical members under compression, handles heavier loads efficiently. The Warren truss, made up of equilateral triangles, disperses loads equally across the structure, distributing tension and compression forces more evenly. However, construction may be more challenging due to the different forces present in its members.

2.2 Modelling in STAAD.Pro and Autodesk Structural Bridge Design

Both designs utilize Grade 275.0 structural steel, with a minimum yield strength of 275 MPa and a 210 GPa Young's modulus, ensuring superior mechanical qualities and high strength and stiffness.

Table 1 *Structural Steel (S 275 Steel)*

Structural Steel	
Nominal Yield Stress	275 N/mm^2
Material Partial factor, Y_m	1
Modulus of Elasticity	210 kN/mm^2
Poission's Ratio, v	0.3
Shear modulus, G	80.769 kN/mm^2
Coefficient of Thermal Expansion	1.2×10^{-5}
Density	77 kN/mm^2
Property Name	Grade 275.0 E 210.0

2.3 Load Definition and Application

Autodesk Structural Bridge Design and STAAD.Pro use loads to design railway bridges. The dead load, representing the self-weight of the bridge's materials, is defined at 44.15 kN/m. The bridge's entire length has a uniform dead load distribution to replicate the constant weight it must support. A significant live load, 1734.54 kN, is applied to account for the dynamic effects of a train, typically applied when the train presses against the tracks. These loads are crucial for showcasing the bridge's response to both static and dynamic forces, ensuring it can support operational demands without compromising structural integrity or safety.

2.4 Structural Analysis

The structural analysis phase involves using defined models and loads for detailed analysis. STAAD.Pro and Autodesk Structural Bridge Design are useful tools for Pratt Truss and Warren Truss designs. STAAD.Pro provides comprehensive modeling and analysis for intricate structural systems, including truss bridges. It supports detailed finite element analysis (FEA) for design validation and optimization. Autodesk Structural Bridge Design offers specialized tools for bridge engineering, making truss analysis more efficient. These software programs help engineers evaluate critical elements for truss bridge structural integrity and functionality.

2.5 Result Comparison

The comparison of STAAD.Pro and Autodesk Structural Bridge Design analyses focuses on Member End Force to understand structural members' internal forces. Cooperative Transfer compares joint displacements to simulate bridge structure elasticity and movement under load. This helps determine the benefits and drawbacks of each software program, including Pratt Truss and Warren Truss bridge types.

3. Result and Discussion

3.1 Design of the Bridge from Both Software

The swing bridge design, utilizing Pratt truss configuration, has been modelled using STAAD.Pro and Autodesk Structural Bridge Design. It measures 90 meters in length, 15 meters in width, and 5 meters in height, with diagonal members measuring 10.2 meters. Images illustrate the design's detailed geometry and structural layout.

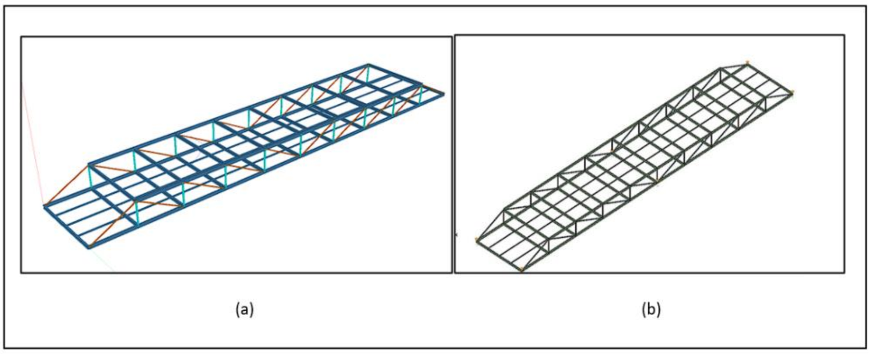

Fig. 3 *Isometric View of the Pratt Truss Bridge, (a) STAAD.pro (b) Autodesk Structural Bridge Design*

The isometric view offers a comprehensive three-dimensional view of the Warren truss bridge, revealing its overall structure and arrangement of truss members, with its equilateral triangle pattern demonstrating uniform load distribution properties.

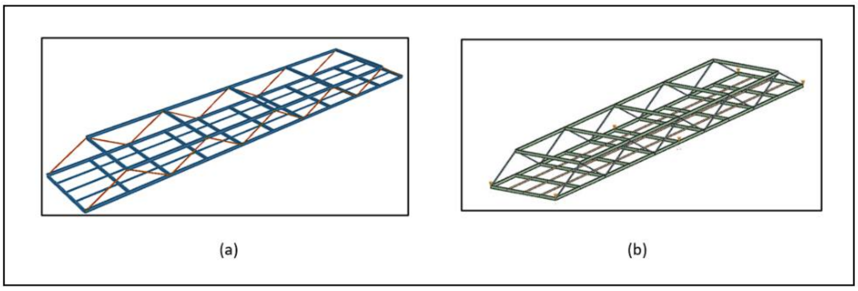

Fig. 4 *Isometric View of the Warren Truss Bridge (a) STAAD.pro (b) Autodesk Structural Bridge Design*

3.2 Comparison Member End Force

Table 2 shows the Pratt Truss analysis results for two beams using STAAD.Pro and Autodesk Structural Bridge Design, illustrating the components of live and dead load along the x-, y-, and z-axes for each software.

Table 2 *Comparison Member End force for Pratt Truss*

Pratt Truss		Dead Load (kN)			Live Load (kN)		
Software	Beam	fx	fy	fz	Fx	fy	fz
STAAD.Pro	1	1290.48	0.031	1.83	50683.82	1.23	71.88
	2	-386.39	0.12	-5.528	-15175.60	4.197	-217.13
Autodesk SBD	1	1290.77	0.06	1.18	59695.31	2.51	46.23
	2	-387.19	0.25	-3.71	-15206.85	9.85	-145.65

3.3 Comparison Joint Displacement

The joint displacement findings for STAAD.Pro and Autodesk Structural Bridge Design Pratt Truss analysis show similar displacements under live, dead, and active loads. Joint 2 moves 2.15 mm under dead load, while Joint 3 moves -4.76 mm under dead load and -0.20 mm under active load.

Table 3 *Comparison Joint Displacement for Pratt Truss*

Pratt Truss		Dead Load (kN)			Live Load (kN)		
Software	Joint	fx (mm)	fy (mm)	fz (mm)	fx (mm)	fy (mm)	fz (mm)
STAAD.Pro	2	2.16	-35.14	0.090	84.87	-1380.15	3.55
	3	-4.89	-52.23	-0.083	-191.99	-2051.33	-324
Autodesk SBD	2	2.15	-34.35	0.06	84.34	-1349.15	-2.39
	3	-4.76	-51.10	-0.20	-187.22	-2006.95	-7.98

Table 5 shows joint displacement findings for Warren Truss analysis using STAAD.Pro and Autodesk Structural Bridge Design. Joint 1 shows -866.50 mm displacement under active load, while Joint 2 shows -888.1 mm under dead load and -3989.21 mm under active load. STAAD.Pro and Autodesk Structural Bridge Design (SBD) are used to analyze Pratt and Warren Truss designs, demonstrating strong member force and joint displacement prediction capabilities. They reliably display large dead and live load forces for Pratt Truss designs and consistently estimate forces and displacements across beams in a Warren Truss study, providing detailed information on structure behavior under various loads. These results highlight the dependability of SBD and STAAD.Pro in bridge-building projects.

4. Conclusion

The comparative analysis of the Pratt truss design using STAAD.Pro provided valuable insights into the intricate truss system, providing a realistic representation of the swing bridge design's geometry and load distribution. The software's consistent and dependable analysis results, including joint displacements and member end forces, demonstrated its ability to forecast the Pratt truss's structural behavior under varied load scenarios. Although slight deviations in numerical results did not significantly affect the overall evaluation, STAAD.Pro's comprehensive insights were useful for swing bridge projects.

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Conflict of Interest

The authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm their contribution to the paper as follows: ***study conception and design:*** *Hanif Naufal Bin Mohd Hassan;* ***data collection:*** *Nik Zikry Bin Zd. Zaibaftar;* ***analysis and interpretation of results:*** *Hanif Naufal Bin Mohad Hassan, Muhammad Syahir Darwish Bin Khairul Anwar;* ***draft manuscript preparation:*** *Nik Zikry Bin Zd. Zaibaftar, Muhammad Syahir Darwish Bin Khairul Anwar. All authors reviewed the results and approved the final version of the manuscript.*

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