MFOB: REVOLUTIONIZING URBAN MOBILITY WITH MOBILE FLYOVER BRIDGE SOLUTIONS

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ABSTRACT

Traffic congestion during road construction causes substantial economic losses and public inconvenience. This study presents the design of a Mobile FlyOver Bridge (MFOB) to mitigate congestion. The MFOB features a retractable, scissor-style structure, primarily made of Aluminum Alloy (A2024) and A36 steel, for its truss ramp and support system. The study used STAAD Pro and ANSYS software for structural modeling, design, and load analysis. The results confirmed the MFOB's capability to carry all vehicle weight classes, with a maximum load capacity of 76.1411 Tons. The load testing under axial and wind forces showed that all structural components, including the links, decks, and shafts, maintained structural integrity under maximum loading, with stresses below the yield strengths of the materials: 363 MPa and 248 MPa for A2024 and A36 steel, respectively. The connection components of the scissor structure and accessories were also designed. Rectangular hollow steel sections were utilized for the design of truss ramp, beams, and columns. The combination of bolted and welded connections was used to ensure safety. The final design measures 5.55 m in length, 4.35 m in width, and 5.27 m in height. It offers a vertical and horizontal clearance of 4.12 m and 3.60 m, respectively. The ramp spans 60.53 m with a 1:12 slope. A mobilization scheme was developed to demonstrate the systematic process that enables efficient deployment. The detailed cost estimation shows that the MFOB is a viable and practical alternative for managing traffic during road reblocking.

Keywords: MFOB, road reblocking, traffic congestion, retractable structure, structural design

INTRODUCTION

Traffic congestion has become a global concern affecting both developed and developing countries, characterized by slower vehicle speeds, longer travel times, and excessive vehicle volumes (Ali & Faraj, 2014). Over time, this issue tends to worsen, particularly when the road design capacity fails to meet actual traffic demand, especially during peak hours. In the United States, traffic congestion costs motorists an average of 42 hours annually and about $733 per driver in lost productivity (INRIX, 2024). A report also noted that nationwide congestion cost the U.S. economy over $70.4 billion in 2023, marking a 15% increase from the previous year (Fernandez, 2024).

The TomTom Traffic Index (2024) evaluated 387 cities across 55 countries and found that London experienced the worst congestion worldwide, with an average travel time of 37 minutes per 10 kilometers. The Philippines ranked ninth, with an average travel time of 27 minutes per 10 kilometers and 105 hours lost annually during rush hours. Car ownership has also risen significantly; in 2022, 13,889,136 vehicles were registered in the Philippines—a 7% increase from the previous year—while new car sales grew by 27% from 2021 (ITA, 2023). The conventional response to congestion has been to expand road capacity. However, studies show that increasing road capacity may initially raise average travel speeds but can also induce greater travel demand, leading to renewed congestion and worsening externalities such as pollution and accidents (Anupriya et al., 2023).

According to Samal et al. (2020), the growing number of vehicles and the increasing population are primary contributors to traffic congestion, resulting in wasted working hours, economic inefficiency, and elevated pollution levels. Congestion not only prolongs travel time and increases fuel consumption but also fosters aggressive driving behavior that may lead to road incidents. Similarly, a study conducted in Chittagong City, Bangladesh, found that port-area congestion led to productivity losses, stress, and environmental costs, resulting in an estimated daily loss of 1.79 million BDT in fuel and 0.10 million BDT in pollution-related expenses (Fattah et al., 2022).

Bull (2003) emphasized that even minor improvements in travel speed could yield economic benefits equivalent to 0.1% of a country's gross domestic product (GDP). Both motorists and public transport users—especially those from lower-income groups—face longer travel times and increased transportation costs due to congestion. Furthermore, all urban residents experience reduced quality of life caused by noise, air pollution, and other negative impacts on health and sustainability. Zhu (2024) noted that traffic congestion can also serve as an economic indicator, as it reflects economic activity; however, when demand for road use exceeds capacity, it results in inefficiency, delays, and commuter frustration.

In the Philippines, urban transport heavily relies on road-based vehicles, including jeepneys, buses, taxis, tricycles, and private cars. Approximately 98% of passenger travel and 60% of freight movement depend on road networks. Metro Manila, with a total road length of 4,889 kilometers, accommodates around 12.8 million daily trips despite its limited road capacity—equating to one kilometer of road for every 385 registered vehicles. The average commuting speed in the region has declined to only 10 kilometers per hour. A report by the Japan International Cooperation Agency (JICA), cited by Recto (2024), estimated that Metro Manila's traffic congestion costs the Philippine economy an estimated ₱3.5 billion daily, which could rise to ₱5.4 billion per day or ₱1.97 trillion annually by 2035 if no significant interventions are implemented.

Overall, traffic congestion imposes substantial economic, social, and environmental costs. It reduces productivity, increases operational expenses, and contributes to stress, accidents, and health problems among commuters. Addressing traffic congestion, therefore, requires sustainable, well-planned transportation strategies that not only enhance mobility but also promote economic growth, environmental protection, and improved urban quality of life.

Traffic Brought by Road Construction

In Nueva Vizcaya (Inquirer North Luzon, 2016), people expressed disappointment with the Department of Public Works and Highways (DPWH) over the ongoing road excavation and repairs along the national route in at least seven towns, which left thousands of drivers stranded for 12 hours. Drivers have had to use single lanes in the towns of Aritao, Bambang, Bayombong, Solano, Bagabag, and Diadi, resulting in an additional three hours of travel time on the national route.

Moreover, road construction has caused intense traffic congestion along the Maharlika Highway, resulting in months of hardship and inconvenience for motorists. The traffic delays in Sta. Fe, a town in southern Nueva Vizcaya, was followed by extended delays as travelers passed through Bagabag and exited the province via Diadi. The road works in Bagabag and Diadi include 38 reblocking and widening projects covering a total of 39.24 km and costing over P1.3 billion. Passengers heading to their flights at NAIA and Clark International Airport expressed frustration after missing their flights due to the lengthy delays encountered in Nueva Vizcaya (Gascon, 2024).

Moreover, poor traffic management during road construction has always been a concern for motorists. In a Calimag news article (2024), Governor Gambito underscored the pressing need for enhanced traffic management, noting that current congestion has resulted in extended delays, increased commuter frustration, and significant economic setbacks for local businesses.

He called for immediate, comprehensive solutions to streamline traffic flow and improve the overall travel experience, both for residents and visitors. Construction-related traffic congestion, travel duration, delays, and queue length make traffic management difficult. Numerous issues, including delays, inconveniences, and financial losses for drivers, are caused by long-term work zones on urban roadways.

The pressing issue of traffic congestion and poor traffic management caused by road construction presented an opportunity for the researchers to propose a Mobile FlyOver Bridge (MFOB) that could address congestion and ensure a smooth, continuous flow of traffic.

Mobile Bridge

The movable bridge system is the best way to restore transportation quickly after both man-made and natural disasters. This bridge should be rapidly transportable, conveniently installed, and disassembled to meet the needs of multi-area reuse and rapid erection in the designated regions (Yu et al., 2021). According to Yan and Aik (2020), deployable structures are structural forms that can transform from a closed, compact, or retracted state into a predetermined extended or deployed shape, where the structures remain stable and capable of bearing loads.

It was noted that transportable and foldable bridges were first used in military operations. These bridges were mounted on top of military tanks, which then carried them to specific areas where military vehicles needed to cross. According to Trevithick (2023), Armored Vehicle Launched Bridges (AVLBs) are part of a new U.S. military support package for Ukraine. These vehicles, based on the Cold War-era M60 Patton tank, can deploy a folding bridge to help allied forces, such as tanks and other heavy vehicles, cross bodies of water and navigate obstacles like trench lines.

The study adapted the concept of ASTRA Bridge, a modular flyover bridge developed by the Swiss Federal Roads Office in 2022, to the Philippine context. The ASTRA Bridge was designed to accelerate road construction projects and enhance safety. By providing a bypass for vehicles, it reduces traffic congestion and improves traffic flow during roadwork. This modular bridge can be easily disassembled and reassembled, enabling its relocation as construction progresses. Furthermore, it offers a safe, weather-protected workspace for road workers, eliminating the need for nighttime operations. Mulach (2024) reported that the Astra Bridge was constructed for 26 million Swiss Francs, equivalent to approximately 1,707,631,380.00 pesos.

This study built upon the work of Gracias (2017), "Design and Fabrication of a Retractable Bridge," which demonstrated the feasibility of constructing a rolling bridge using a pneumatic system powered by compressors and pneumatic cylinders. This type of bridge could be particularly useful in locations where laying foundations on both sides of a canal or river is difficult, or where the budget is limited compared to that for conventional bridges. Gracias examined the internal mechanisms of pneumatic cylinders, highlighting how they enable the piston to move back and forth, as in hydraulic cylinders. He emphasized that one advantage of using pneumatics in bridge construction is their cleaner and quieter operation, as well as their lack of need for large fluid storage, unlike hydraulic systems, such as those used in the bridge constructed in Paddington. Gracias also noted that because the operating fluid in pneumatics is compressed air, any leakage would not result in dripping or environmental contamination.

Rosendo et al. (2020) proposed a potential solution: a transportable folding bridge. This innovative design combines the functionality of a temporary bridge with the mobility of a movable one. Composed of modular components that fold into a compact configuration, this bridge can be easily transported to disaster-stricken areas and deployed to connect isolated communities.

To ensure efficient deployment and structural integrity, the bridge must be lightweight yet strong. This necessitates the use of materials with low density and high yield strength. Additionally, strategically placed holes in the bridge's components can further reduce weight without compromising its load capacity. The ability to fold into a smaller size is crucial for efficient transportation and deployment in remote locations, as outlined in the study. To complete their study, Resendo et al. utilized the Finite Element Method (FEM) to analyze the bridge. They employed ANSYS 2019 R3, a software application that applies FEM to evaluate structural behavior and determine the actual stress experienced by a bridge.

Furthermore, the study by Soudagar & Anand (2022) focused on a novel type of movable, foldable bridge, the scissor bridge. The fundamental operating principle of this bridge is based on a scissor mechanism. These bridges are particularly useful in military operations and can be deployed over obstacles where space is limited, functioning as either bascule or vertical lift movable bridges. The design allows the bridge to expand and retract along a plane parallel to the ground, facilitating storage when not in use.

In this study, a bridge with a span of 8 meters, a width of 5.5 meters, and a height of 8 meters was modeled in STAAD Pro for a moving-load analysis. The analysis considered the IRC Class AA tracked load for evaluating moving loads. The structural analysis was conducted for both dead loads and the IRC Class AA tracked load, and the results were within the permissible limits established by Indian design codes. The maximum deflection observed was 14.337 mm, which is below the allowable deflection limit of 45.83 mm for the specified load combinations, indicating that the structure is safe with respect to deflection. Additionally, the maximum shear force and bending moments experienced by the structure under the specified load combinations were found to be less than the design shear force and bending moment calculated in accordance with IS 800:2007. Given that the structure can safely accommodate the IRC Class AA tracked load of 700 kN, it is deemed suitable for military applications.

The study of Biro & Bakar (2013) aimed to develop a lightweight, foldable scissor bridge, simulate its movement, and evaluate its structural performance. The bridge mechanism was designed using Kutzbach's equation, ensuring two degrees of freedom with a defined number of links and joints. It is important to note that the design parameters did not account for variations in ground elevation or damping effects during flooding scenarios. Such factors, particularly soil damping, are prevalent in riverine areas and during periods of heavy rainfall. Fiber-reinforced polymer (FRP) was identified as the material to be used, as the limitations of ANSYS's material library necessitated the use of A36 structural steel for numerical simulations.

Ario (2013) from Hiroshima University introduced the Mobile Bridge, a foldable emergency bridge designed to support disaster relief efforts in response to Japan’s long history of natural disasters, including earthquakes, floods, tsunamis, and landslides. Japan has suffered significant infrastructure damage from disasters such as the Great Hanshin-Awaji Earthquake in 1995, the Tohoku Earthquake and Tsunami in 2011, and bridge damage caused by typhoons in areas such as Hokkaido, Tohoku, and Kagoshima. The Mobile Bridge features an innovative origami-inspired design that enables compact storage and rapid deployment, making it highly effective for emergency use. Recognized in the engineering category, it has been praised by Popular Science as "the world's fastest, strongest, lightest temporary bridge" for its exceptional performance and practicality.

The researchers chose the title “MFOB” for this study because it is an acronym for mobile flyover bridge. Moreover, it is the initials of the researchers: Michael, Francis, Owen, and Brandon. This study aimed to innovate and design a mobile flyover and retractable bridge that can be deployed during road repair and construction. This offers a promising solution for decongesting high traffic volume.

Therefore, the researchers proposed the MFOB, a scissor bridge made of steel that can be assembled and disassembled within a short period. Building on the concept of the ASTRA Bridge (2022), which provides a bypass road to alleviate traffic congestion and improve traffic flow during road construction, this study aimed to enhance these benefits. It utilized the findings of Gracias (2017), who developed a rolling bridge using a pneumatic system powered by compressors and pneumatic cylinders, serving as a support mechanism for the mobile flyover bridge. Additionally, the researchers drew upon the scissor-type retractable bridge by Biro & Bakar (2013), the mobile bridge developed by Hiroshima University (2013) in Japan, and the bridge designed by Rosendo et al. (2020) in the Philippines to develop a retractable and movable steel bridge.

The MFOB will be transported by trailers. The support structure consists of beams and columns, and the scissor structure will be assembled using a mobile crane. Each bridge section is connected using frame connectors that will be assembled by workers. The MFOB will be extended from its folded form using a hydraulic cylinder. Once fully extended, a locking system will secure the bridge, ensuring stability. The estimated assembly time for the MFOB is at least 3 hours, which was based on ASTRA and the estimated time of transport will depend on the location of the road reblocking. Another key feature of MFOB is its mobility. Equipped with wheels, it can move forward as construction progresses without disassembly, offering significant convenience. Additionally, a ramp will be used for the entry and exit of vehicles on the bridge. Moreover, there is a designated space for the entry and exit of construction vehicles such as rollers and mixers. The height of the mobile flyover bridge is carefully designed to accommodate construction vehicles that need to pass underneath. A hydraulic jack support system will be used to adjust the bridge's height.

Conceptualization

The conceptualization phase involved identifying and selecting potential research problems that could be addressed through engineering concepts. After evaluating various problems and proposing solutions, the researchers narrowed the scope of the research problem for further development. To ensure the project's rigor and feasibility, the researchers sought the guidance of a qualified adviser to provide expert insights and support throughout the study's development.

Data Collection

In this phase, the researchers gathered data from the Department of Public Works and Highways (DPWH) and obtained information on bridge design specifications. The vehicle weight classifications were taken from the Alternative Fuels Data Center website. This data collection formed a critical foundation in the analysis and design of MFOB.

Setting and Integrating Design Parameters

The researchers used the collected data to define the scope and requirements of the study. In particular, the design parameters for the MFOB were considered. The height and width were precisely calibrated to accommodate the dimensions of vehicles and ensure adequate clearance for equipment used in road construction. The material used was steel, with a high strength-to-weight ratio. This design conformed with engineering standards, optimizing the bridge's functionality, safety, and integration with existing traffic infrastructure.

Design Analysis and Modeling

The design and analysis aimed to investigate the behavior of the structural components in detail. The study utilized STAAD Pro and ANSYS. The researchers designed each structural component using trial sections and tested it individually. The structure, composed of the final designs of its structural components, was constructed virtually and thoroughly evaluated under various load conditions to assess its overall performance and stability. The analysis enabled a comprehensive assessment of stresses and deformation. The findings contributed to the optimization of design parameters, ensuring structural integrity and adherence to engineering standards. The researchers also created a 3D printed scale model to provide a tangible representation of the MFOB and its mechanism.

Cost Estimation

Upon the completion of the MFOB design, a detailed cost estimation was conducted. This quantity computation and cost estimation accounted for all materials, ensuring a comprehensive estimation of the MFOB.

Drawing of Conclusion and Recommendation

The conclusions and recommendations were based on the comprehensive analysis of the MFOB design.

METHODOLOGY

Research Design

This study included gathering, designing, and illustrating data to develop a Mobile FlyOver Bridge (MFOB) design, presented in figures and images. It was limited to assessing the MFOB's structural stability, capacity, and cost estimation. The materials used were steel, with a high strength-to-weight ratio. A high-strength-to-weight ratio material was suitable, as the MFOB was designed to be lightweight for easy transport and quick assembly while maintaining strength. The study also utilized STAAD for the design and analysis of the structural components. It also used ANSYS, a robust engineering simulation tool that employs the Finite Element Method (FEM) to model and simulate various real-world load conditions. It investigated the maximum load capacity of the MFOB. The simulation results were used to develop the final design, technical plans, and conclusions.

Research Locale

The study was conducted at Saint Mary's University (SMU) in the Academic Year 2024-2025. It is located in Barangay Don Mariano Marcos, Bayombong, Nueva Vizcaya, Philippines.

Research Instruments

The following instruments were used in the study:

- AutoCAD - A computer-aided design software for precise 2D design and drafting. It was used to draw the technical plans of the proposed portable bridge.
- SketchUp - SketchUp is a 3D modeling program that can be used in a 2D environment to create 3D objects. It was used to create the 3D model.
- Microsoft Excel - Microsoft Excel is a spreadsheet program that allows users to organize, format, and calculate data in a grid of cells. It was used in the cost estimation.
- ANSYS - ANSYS is a software that provides engineering simulation tools for various engineering fields. It was used to model, analyze, and solve complex problems to attain better results on the proposed design.
- Lumion – Lumion is a 3D visualization software used to create realistic renderings and animations of architectural projects.
- STAAD – STAAD is a software program used by civil engineers to analyze and design structures. It can perform 3D structural analysis and design for a variety of structures.

Design Criteria

The following design criteria were used in the study:

- National Structural Code of the Philippines (NSCP 2015 Edition) - This code contains the minimum requirements and codes for designing structures.
- Bridge Design (DGCS Vol 5) of the Department of Public Works and Highways (DPWH) - It contains the design criteria, guidelines, and standard bridge specifications that will be used for the structural analysis.
- ASEP Steel Handbook 2004 (3rd Edition) - a reference for steel sections and their properties
- American Institute of Steel Construction (AISC) - a reference for steel sections and their properties.

Data Gathering Procedure

The researchers gathered data on vehicle weight classes and categories from the Alternative Fuels Data Center website, which provided complete data on the vehicle weight classes used in the study. The weight of each vehicle was loaded on the bridge in the design and analysis phase, and the maximum load capacity of the MFOB was determined. The provision for load factors, particularly for dead load, vehicle live load, and wind load, was based on "Design Rules, Criteria, and Standards for Bridge Design (DGCS Volume 5)" of the DPWH. The researchers also conducted site visits to road construction and reblocking sites and observed the working zones, which supplemented the design of MFOB. The 3.35 m width of the national road was considered in the design to ensure accessibility for all vehicles. Moreover, the height of MFOB was designed to exceed that of a concrete mixer truck used in construction (3.75 m) to provide vertical clearance and ensure a safe working zone.

Treatment of Data

The data obtained served as the foundation for the design and analysis. Subsequently, the data gathered from the DPWH, along with the proposed plan, was incorporated into the design of the MFOB. Based on the data gathered and from recent studies, the researchers established the initial dimensions of the MFOB's scissor structure. The preliminary width was 4 meters, the height was 4.5 meters, the length of a single span was 5.5 meters, and the length of the scissor structure's link was 1.9 meters, with an inclination of 45 degrees from the horizontal. The structural components, particularly the beams and columns, truss ramp, and their connections, were designed using STAAD. The bridge's load capacity was determined by utilizing ANSYS. An engineering simulation software that allows engineers to test virtually and analyze the designed structure, optimizing safety and efficiency. After setting the initial dimensions and designing the structural components, a trial test was conducted, applying each vehicle's class weight. The safety and adequacy of the design were also determined. The analysis results served as the basis for the researchers' decision on whether to adopt the initial design or redesign the structural components to ensure the bridge's safety and capacity.

RESULTS AND DISCUSSION

This chapter presents the findings and interpretations of data from simulations and load testing of the MFOB and its main structural components. It also includes the design of each structural component and connections. The special features and mechanical configurations of the MFOB are also presented.

MFOB Parameters

The MFOB's designed span has a length of 5.55 m, a width of 4.35 m, and a height of 5.27 m from the floor line to the deck. It has a vertical clearance of 4.12 m from the floor line to the bottom of the beam and a horizontal clearance of 3.6 m. The designed ramp has a total length of 60.53 m with a slope of 1/12. The retracted spans for the bridge and ramp are 2.10 m and 1.8 m, respectively. The columns of the designed span have a total height of 5.27 m and a retracted height of 3 m.

Figure 1
Bridge & Ramp Components

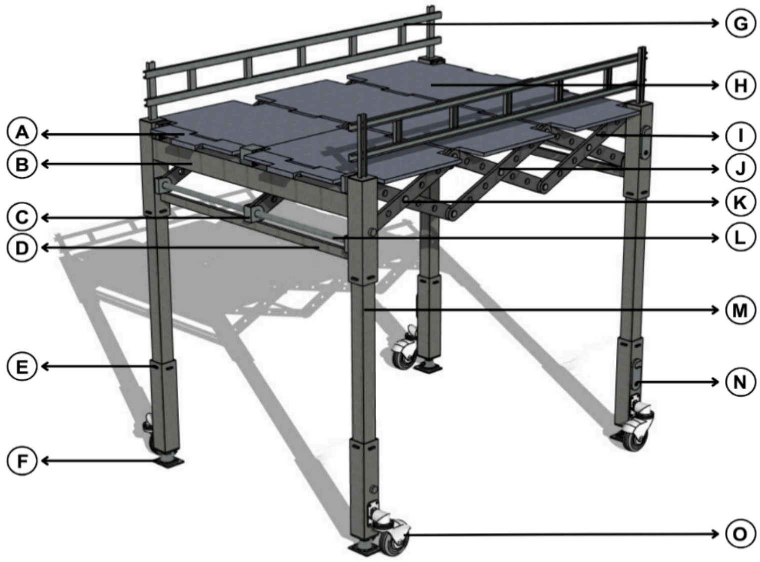
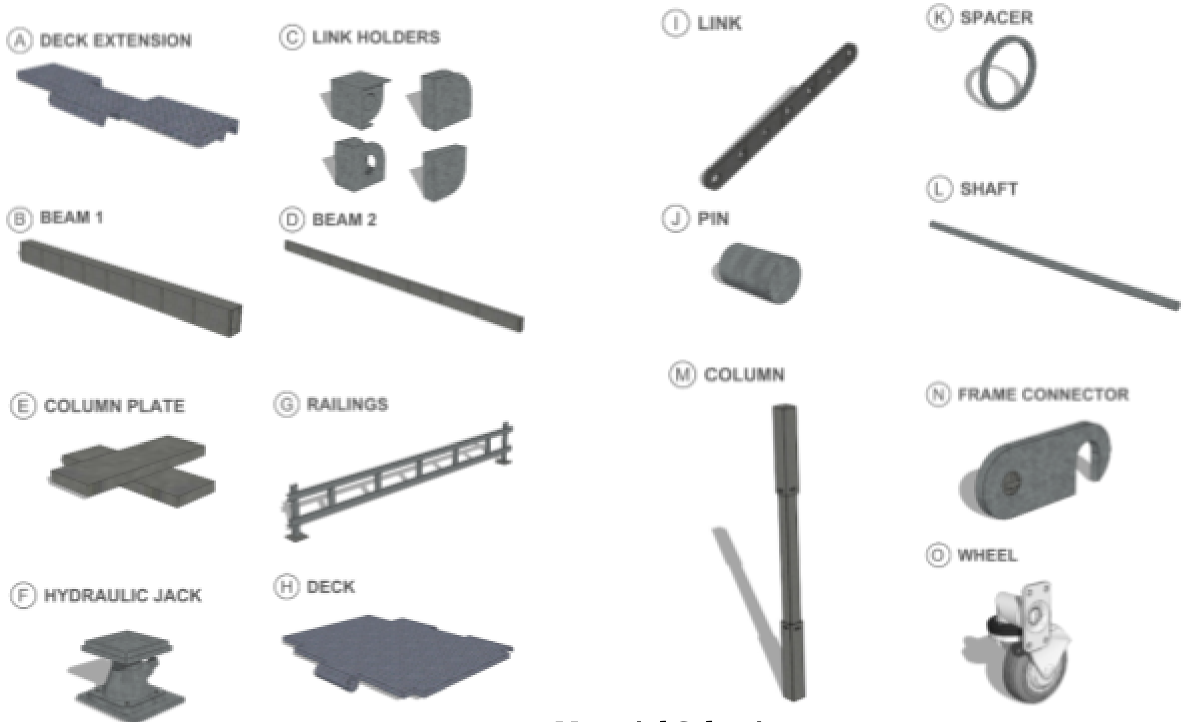


Figure 2
Bridge Components



Material Selection

The researchers utilized two types of material in the design of MFOB. The aluminum alloy (A2024) was used to design the scissor structure, and the A36 steel was used to design the columns. The researchers selected aluminum alloy (A2024) due to its exceptional combination of lightweight characteristics and high strength, making it an ideal material for structural applications. Aluminum is about one-third the weight of steel, making the MFOB easier to handle and reducing the structure's dead load. It also provides high strength, making it suitable for structural applications. It has high corrosion resistance, making it ideal for outdoor structures,

Table 1
Material Properties

MATERIAL	DENSITY	YIELD STRENGTH	ULTIMATE STRENGTH
A36 STEEL	7850 kg/m^3	248 MPa	414 MPa
A2024 ALUMINUM ALLOY	2770 kg/m^3	363 MPa	494 MPa

Source: *ANSYS Engineering Data Sources*

bridges, and coastal buildings exposed to moisture and harsh weather.

Design Loads and Specifications

The design loads used to test the bridge and ramp scissor structures in the study were calculated based on Table 10.3-1, Table 10.3-2, and Table 10.13.1.1-1 of the Design Rules, Criteria, and Standards for Bridge Design Volume 5 (DGCS Vol. 5) as presented in Figure 12. The researchers chose the Strength-III limit state for the load combination because the bridge will be exposed to wind velocities exceeding 90 km/h.

Figure 3
DGCS Vol. 5 Load Provisions

Table 10.3-1 Load Combination and Load Factors

Load Combination / Limit State	DC DD DW EH EV ES EL PS CR SH	LL IM CE BR PL LS	WA	WS	FR	TU	TG	SE	EQ	Use one of these at a time: BL	CT	CV
STRENGTH-I (Unless noted)	γ_p	1.75	1.00	-	1.00	0.50/1.20	0.0	γ_{SE}	-	-	-	-
STRENGTH-II	γ_p	1.35	1.00	-	1.00	0.50/1.20	0.0	γ_{SE}	-	-	-	-
STRENGTH-III	γ_p	1.35	1.00	-	1.00	0.50/1.20	0.0	γ_{SE}	-	-	-	-
STRENGTH-III	γ_p	-	1.00	1.4	1.00	0.50/1.20	0.0	γ_{SE}	-	-	-	-
STRENGTH-IV	γ_p	-	1.00	-	1.00	0.50/1.20	-	-	-	-	-	-
EH, EV,ES,DW,	1.5											
DC ONLY												
STRENGTH-V	γ_p	1.35	1.00	0.40	1.00	0.50/1.20	0.0	γ_{SE}	-	-	-	-
EXTREME EVENT - I	γ_p	γ_{EQ}	1.00	-	1.00	-	-	-	1.00	-	-	-
EVENT - I												
EXTREME EVENT - II	γ_p	0.5	1.00	-	1.00	-	-	-	-	1.00	1.00	1.0 0
EVENT - II												
SERVICE - I	1.00	1.00	1.00	0.30	1.00	1.00/1.20	0.0	γ_{SE}	-	-	-	-
SERVICE - II	1.00	1.3	1.00	-	1.00	1.00/1.20	-	-	-		-	-
SERVICE - III	1.00	0.8	1.00	-	1.00	1.00/1.20	0.0	γ_{SE}	-	-	-	-
SERVICE - IV	1.00	-	1.00	0.70	1.00	1.00/1.20	–	1.0	-	-	-	-
FATIGUE – 1 LL, IM, & CE ONLY	-	1.50	-	-	-	-	-	-	-	-	-	-
FATIGUE – II LL, IM, & CE ONLY	-	0.75	-	-	-	-	-	-	-	-	-	-

Table 10.3-2 Load Factors for Permanent Loads, γ_p

Type of Load	Load Factor: Max	Min
DC: Component and Attachments	1.25	0.90
DD: Downdrag	1.80	0.45
DW: Wearing Surfaces and Utilities	1.50	0.65
EH: Horizontal Earth Pressure		
Active	1.50	0.90
At-Rest	1.35	0.90
EL: Locked-in Erection Stresses	1.00	1.00
EV: Vertical Earth Pressure		
Retaining Walls and Abutments	1.35	1.00
Rigid Buried Structure	1.30	0.90
Rigid Frames	1.35	0.90
Flexible Buried Structures other than Metal Box Culverts	1.95	0.90
Flexible Metal Box Culverts	1.50	0.90
ES: Earth Surcharge	1.50	0.75

Table 10.13.1.1-1 Base Pressure, P_B Corresponding to V_B=160 km/h

Superstructure Component	Windward Load (Mpa)	Leeward Load (Mpa)
Trusses, Columns and Arches	0.0024	0.0012
Beams	0.0024	NA
Large Flat Surfaces	0.0019	NA

Source: Design Rules, Criteria, and Standards for Bridge Design Volume 5

Dead Load

Dead loads are the permanent, static loads that remain constant over time in a structure. These loads include the weight of the structure itself and any fixed components that do not change position. The dead load used for the analysis of the scissor structure is the gross weight of all the scissor's structural components. The total dead load of a single span of the bridge and ramp scissor is 43.58106 KN and 42.04016 KN, respectively. The units of load are expressed in KN because the design loads in DGCS Vol. 5 are expressed in KN.

Live Load

Live loads are the temporary, variable loads that a structure experiences due to occupants or vehicles. These loads can change over time in magnitude and location. The live load used for the analysis of the scissor structure is the gross vehicle weight of each vehicle class as presented in Figure 13.

Figure 4

Vehicle Weight Class and Categories

Gross Vehicle Weight Rating (lbs)	Federal Highway Administration	
	Vehicle Class	GVWR Category
> 6,000	Class 1: < 6,000 lbs	Light Duty < 10,000 lbs
10,000	Class 2: 6,001 – 10,000 lbs	
14,000	Class 3: 10,001 – 14,000 lbs	Medium Duty 10,001 – 26,000 lbs
16,000	Class 4: 14,001 – 16,000 lbs	
19,500	Class 5: 16,001 – 19,500 lbs	
26,000	Class 6: 19,501 – 26,000 lbs	
33,000	Class 7: 26,001 – 33,000 lbs	Heavy Duty > 26,001 lbs
> 33,000	Class 8: > 33,001 lbs	

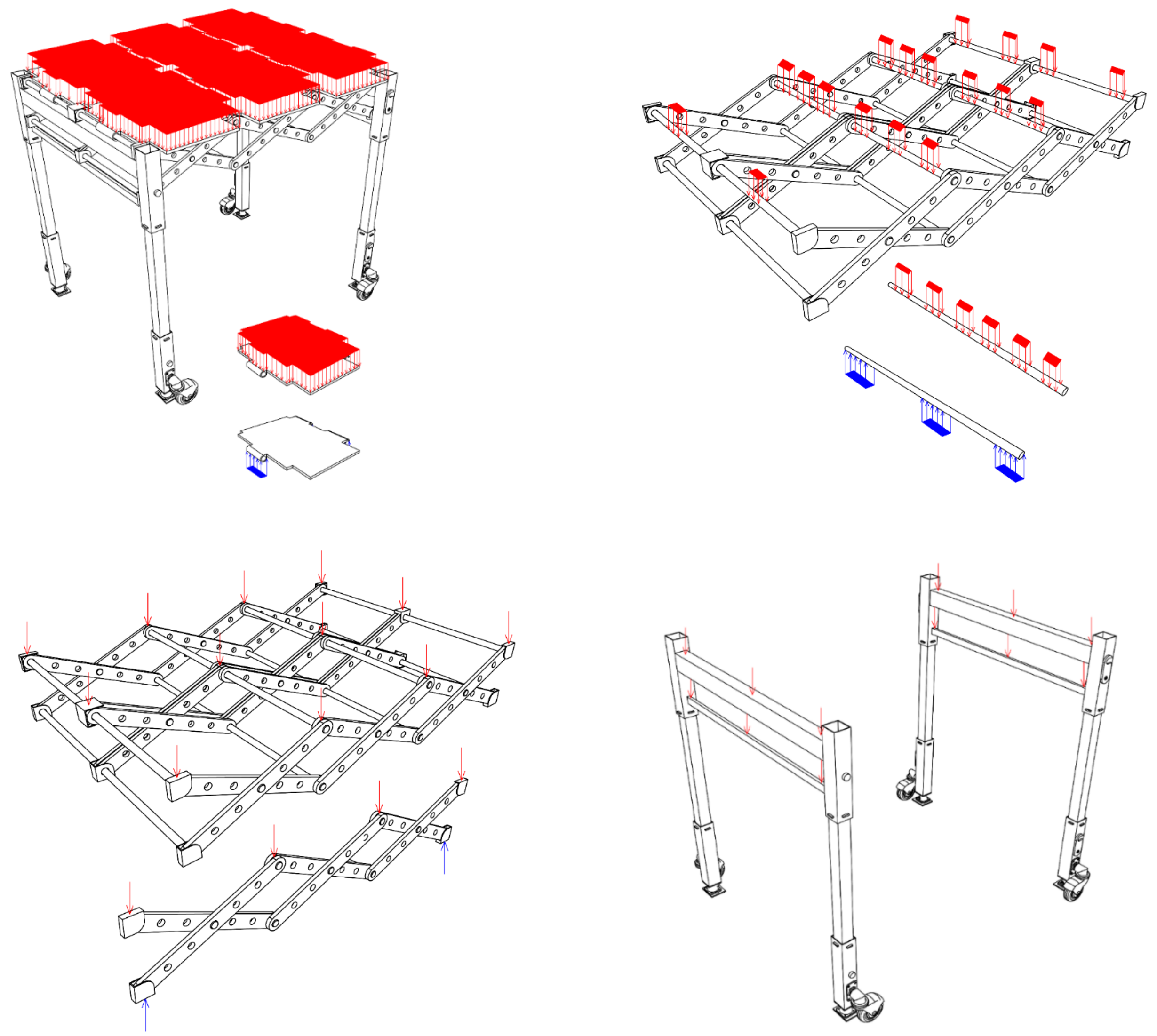
Wind Load

Wind load is the force exerted by wind on a structure. It is an important factor in structural design, especially for bridges and exposed structures. The wind pressures used are based on Table 10.13.1.1-1 of DGCS Vol. 5, which has a base pressure corresponding to a wind velocity of 160 km/h. The leeward and windward pressures used are 0.0024 MPa and 0.0012 MPa, respectively.

Load Distribution

Load distribution is the process by which applied loads on a structure are spread and transferred through its various structural components. In the case of the Mobile Flyover Bridge (MFOB), load distribution begins at the deck, which receives applied loads, such as vehicular weight, and transfers them to the shafts. From the shafts, the loads are transmitted to the links, which serve as connecting elements to the bridge frame. The reactions from the links are then transferred to the beams, which in turn distribute the loads to the columns. The columns ultimately carry and transfer the loads down to the ground through the hydraulic jack support system.

Figure 5
Load Distribution



Analysis and Design of Aluminum Bridge and Ramp Structural Components

The researchers designed the dimensions of each structural component based on the bridge parameters. The ANSYS software was used to test each component's performance in terms of total deformation, maximum principal stress, and maximum shear stress under loading. The stress results must not exceed the material's yield strength to conclude that the designed dimensions are safe. The support used in the testing is fixed support. The testing used axial loads and wind loads. The axial loads applied were gross vehicle weights taken from the Vehicle Weight Classes and Categories. The wind pressures applied were taken from Table 10.13.1.1-1 of DGCS Vol. 5.

Design of Aluminum Bridge Link and Ramp Link

The link is the major component of the MFOB's scissor structure. It is an assembly of mechanically connected bodies that enables the MFOB's retraction and expansion features. The links were designed with holes to make them lighter while having the strength to carry loads. This also helps the links to have less stress when subjected to wind loads.

Table 2
Axial Load Test Result Summary - Bridge Link

VEHICLE CLASS	AXIAL LOAD (KN)	TOTAL DEFORMATION (mm)	MAXIMUM PRINCIPAL STRESS (MPa)	MAXIMUM SHEAR STRESS (MPa)	REMARKS
2	26.72244	0.52757	23.324	12.565	Passed
3	44.5374	0.87929	38.873	20.941	Passed
4	62.35236	1.231	54.422	29.318	Passed
5	71.25984	1.4069	62.197	33.506	Passed
6	86.84793	1.7	75.154	40.487	Passed
7	115.7972	2.2666	100.21	53.982	Passed
8	146.9734	2.8724	126.98	68.408	Passed

Source: *ANSYS Solution*

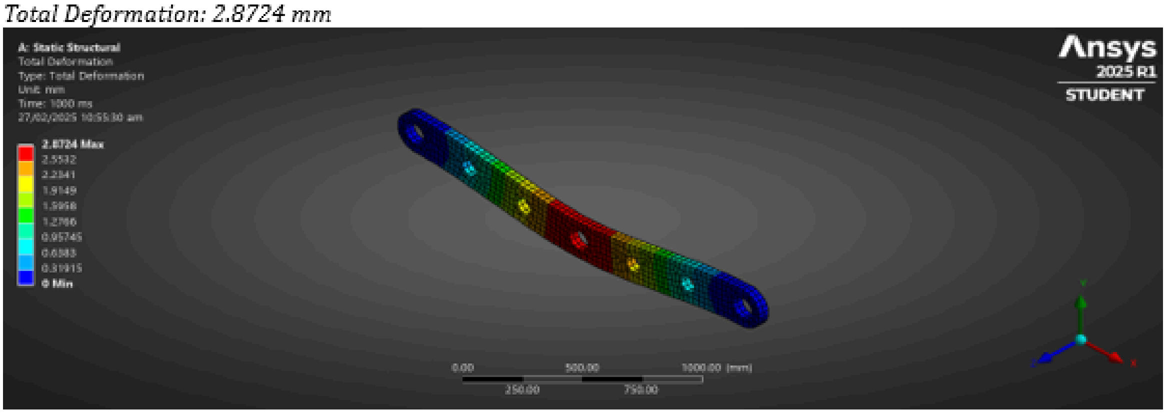
Table 3
Axial Load Test Result Summary - Ramp Link

VEHICLE CLASS	AXIAL LOAD (KN)	TOTAL DEFORMATION (mm)	MAXIMUM PRINCIPAL STRESS (MPa)	MAXIMUM SHEAR STRESS (MPa)	REMARKS
2	26.7224	0.53298	20.877	12.646	Passed
3	44.5374	0.8883	34.794	21.077	Passed
4	62.3523	1.2436	48.712	29.507	Passed
5	71.2598	1.4213	55.671	33.722	Passed
6	86.8479	1.7174	67.269	40.748	Passed
7	115.7972	2.2898	89.692	54.331	Passed
8	146.9734	2.9018	113.66	68.85	Passed

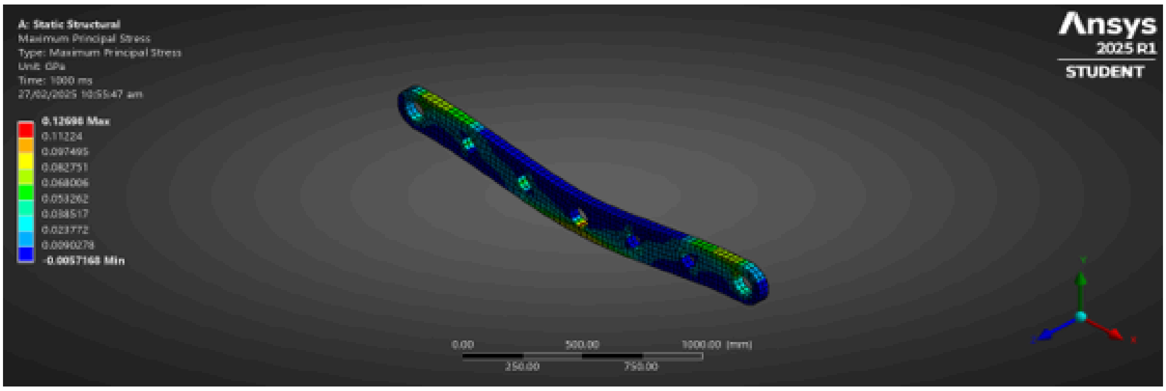
Source: *ANSYS Solution*

Figure 6
Axial Load Test - Bridge Link

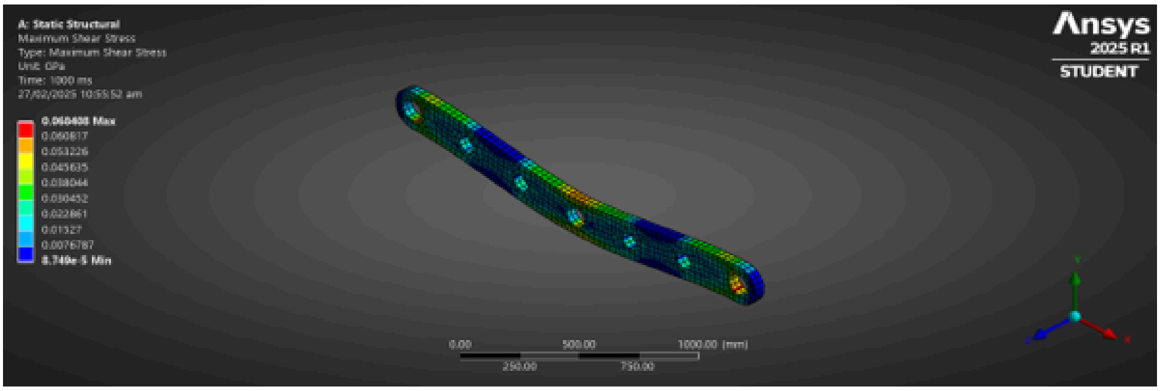
Total Deformation: 2.8724 mm



Maximum Principal Stress: 126.98 MPa



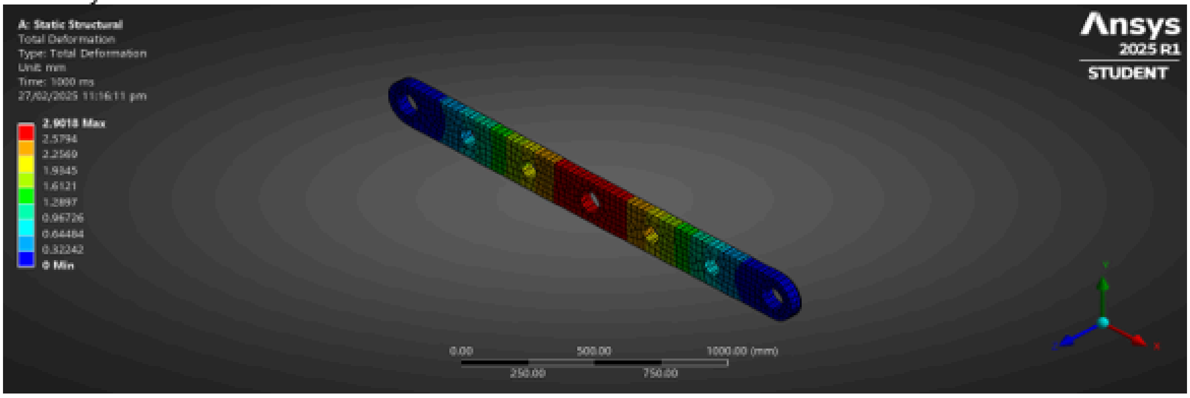
Maximum Shear Stress: 68.408 MPa



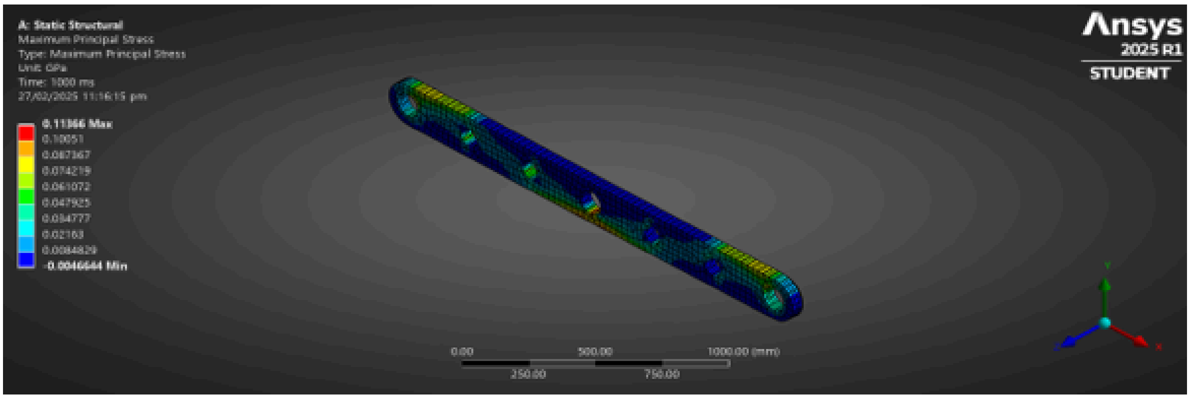
Source: *ANSYS Solution*

Figure 7
Axial Load Test - Ramp Link

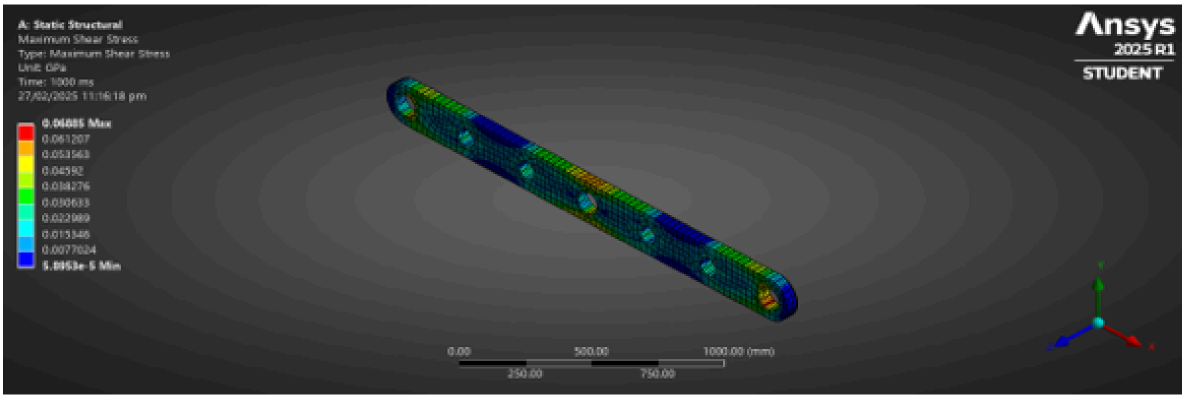
Total Deformation: 2.9018 mm



Maximum Principal Stress: 113.66 MPa



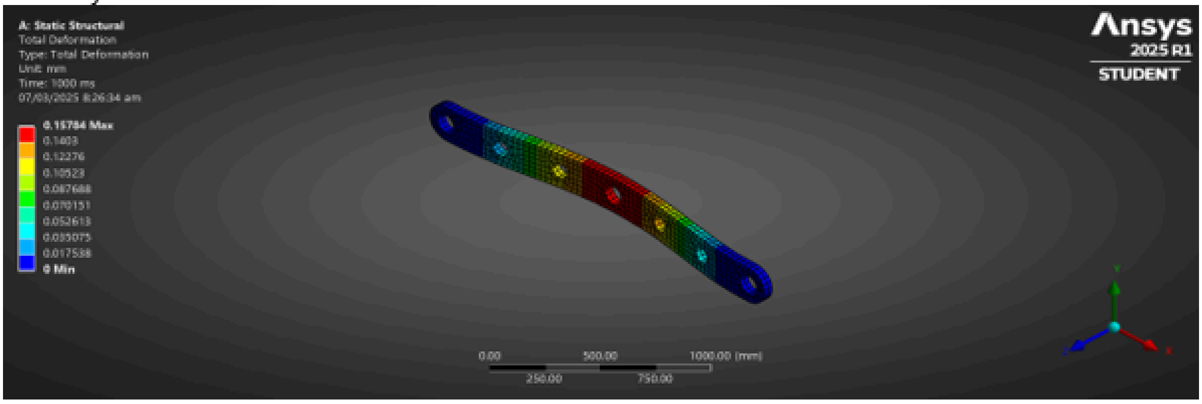
Maximum Shear Stress: 68.85 MPa



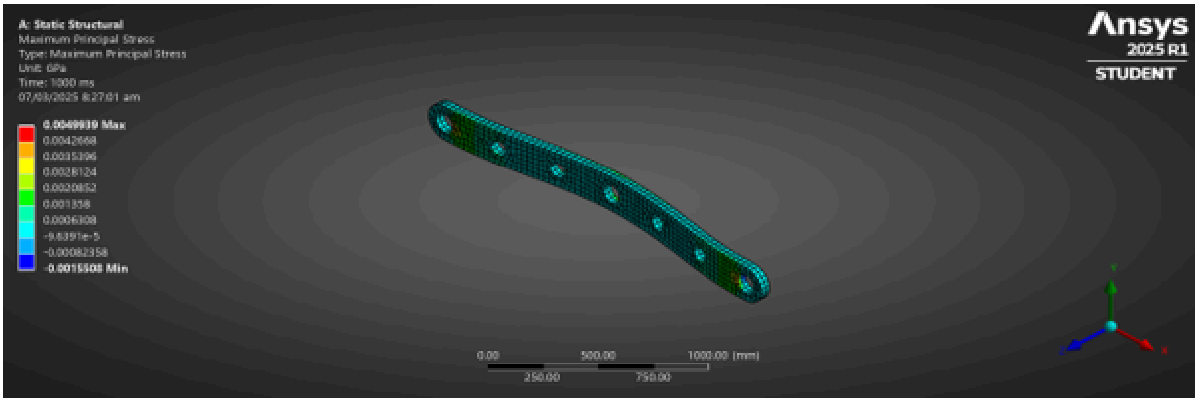
Source: *ANSYS Solution*

Figure 8
Wind Load Test - Bridge Link

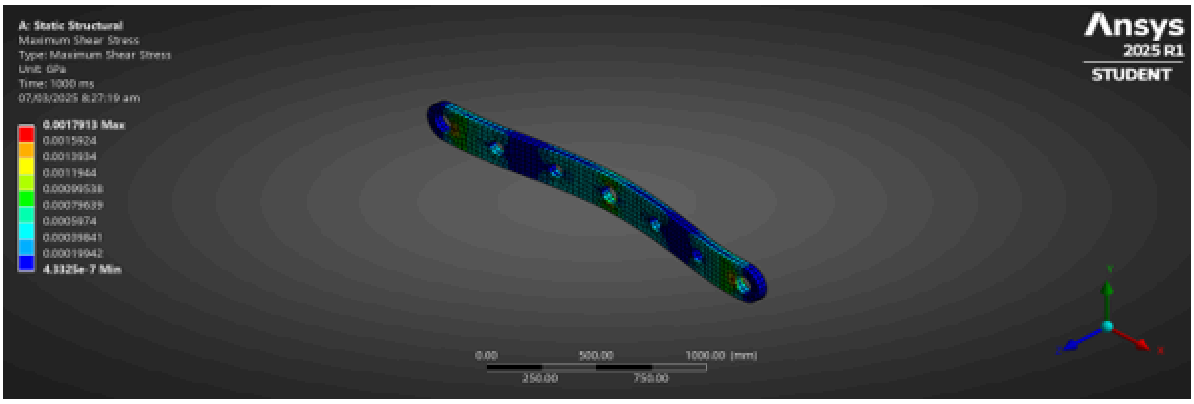
Total Deformation: 0.15784 mm



Maximum Principal Stress: 4.9939 MPa



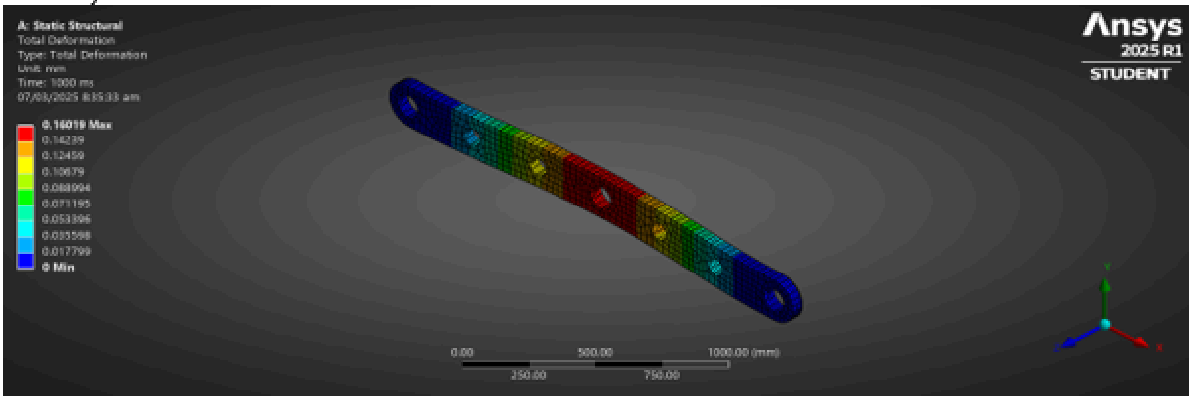
Maximum Shear Stress: 1.7913 MPa



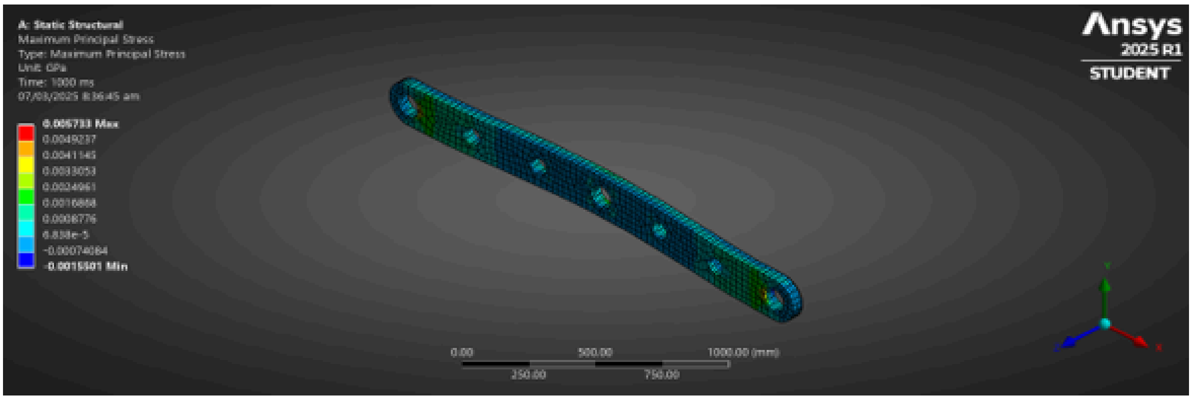
Source: *ANSYS Solution*

Figure 9
Wind Load Test - Ramp Link

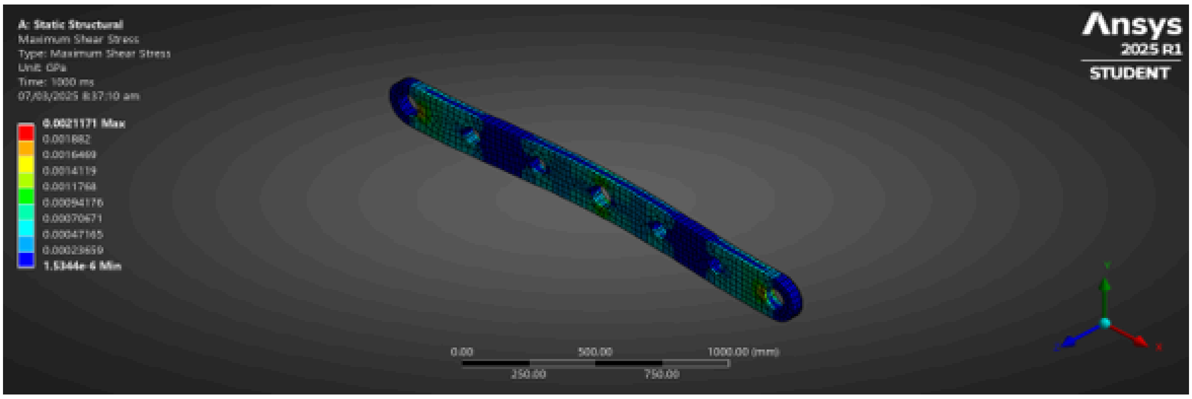
Total Deformation: 0.16019 mm



Maximum Principal Stress: 5.733 MPa



Maximum Shear Stress: 2.1171 MPa



Source: *ANSYS Solution*

The data presented in Tables 2 and 3 show that the bridge and ramp links passed the axial load test, obtaining maximum principal stress and maximum shear stress values that are less than the material's yield strength. Table 4 also shows that the bridge and ramp links passed the wind load tests. It was proven that the assumed thickness and holes provided are safe.

Design of Aluminum Bridge Deck and Ramp Deck

The deck is the main component that allows traffic to pass through MFOB. Decks are mechanically connected via shafts that allow them to fold during retraction and expansion. The loads applied to test the deck's maximum capacity and strength are axial loads. The decks were designed to have a thickness adequate to carry all vehicle classes.

Table 5
Axial Load Test Result Summary - Bridge Deck

VEHICLE CLASS	AXIAL LOAD (KN)	TOTAL DEFORMATION (mm)	MAXIMUM PRINCIPAL STRESS (MPa)	MAXIMUM SHEAR STRESS (MPa)	REMARKS
2	26.7224	1.6076	23.737	13.585	Passed
3	44.5374	2.6794	39.562	22.641	Passed
4	62.3523	3.7511	55.387	31.697	Passed
5	71.2598	4.287	63.3	36.226	Passed
6	86.8479	5.1801	76.487	43.773	Passed
7	115.7972	6.9068	101.98	58.364	Passed
8	146.9734	8.7526	129.24	73.961	Passed

Source: *ANSYS Solution*

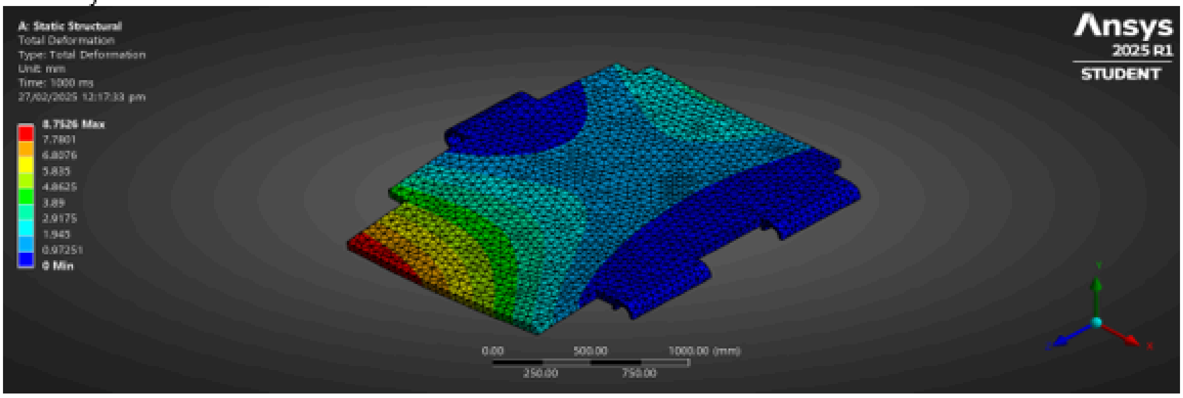
Table 6
Axial Load Test Result Summary - Ramp Deck

VEHICLE CLASS	AXIAL LOAD (KN)	TOTAL DEFORMATION (mm)	MAXIMUM PRINCIPAL STRESS (MPa)	MAXIMUM SHEAR STRESS (MPa)	REMARKS
2	26.7224	0.19871	3.6193	1.8825	Passed
3	44.5374	0.33119	6.0322	3.1375	Passed
4	62.3523	0.46366	8.4451	4.3925	Passed
5	71.2598	0.5299	9.6516	5.02	Passed
6	86.8479	0.64029	11.662	6.0659	Passed
7	115.7972	0.85372	15.55	8.0878	Passed
8	146.9734	1.0819	19.705	10.249	Passed

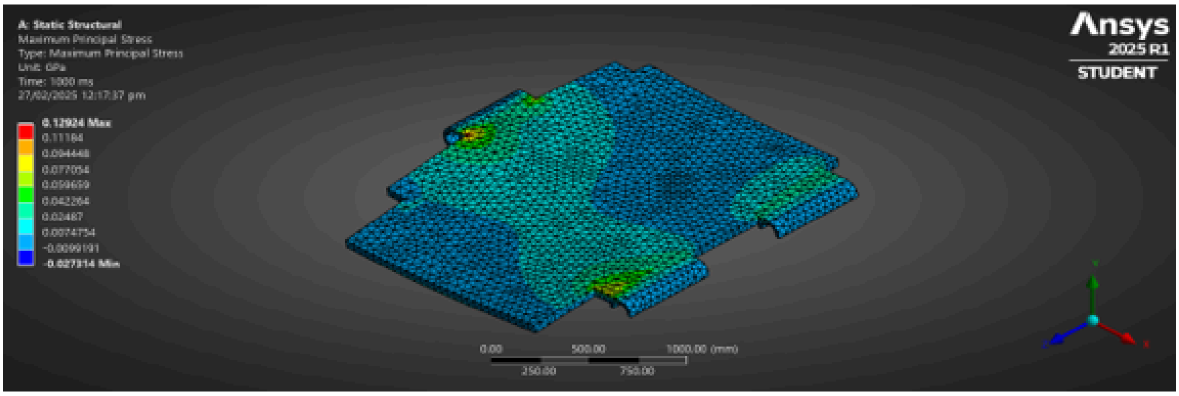
Source: *ANSYS Solution*

Figure 10
Axial Load Test - Bridge Deck

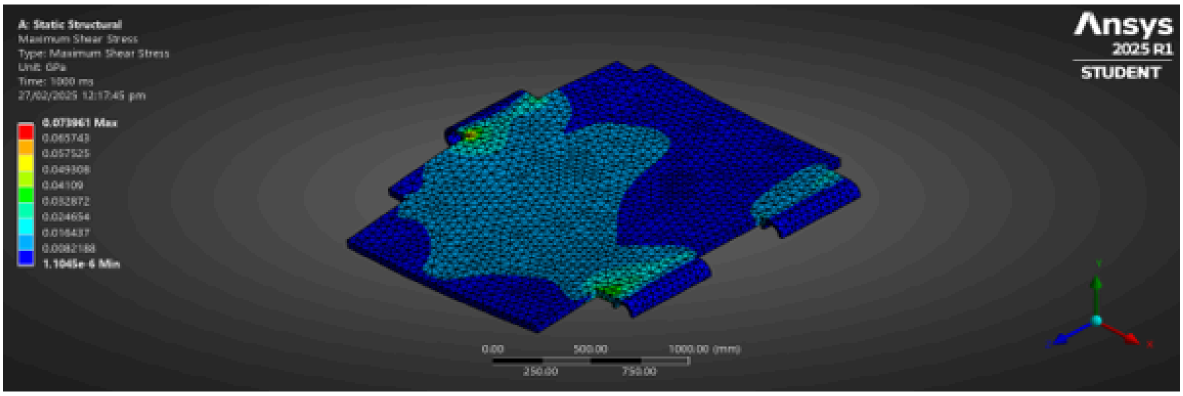
Total Deformation: 8.7526 mm



Maximum Principal Stress: 129.24 MPa



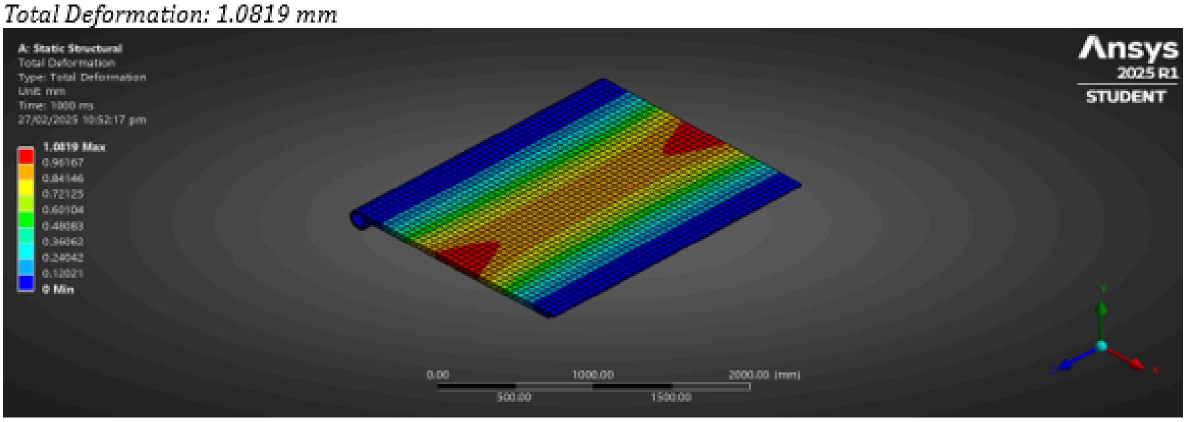
Maximum Shear Stress: 73.961 MPa



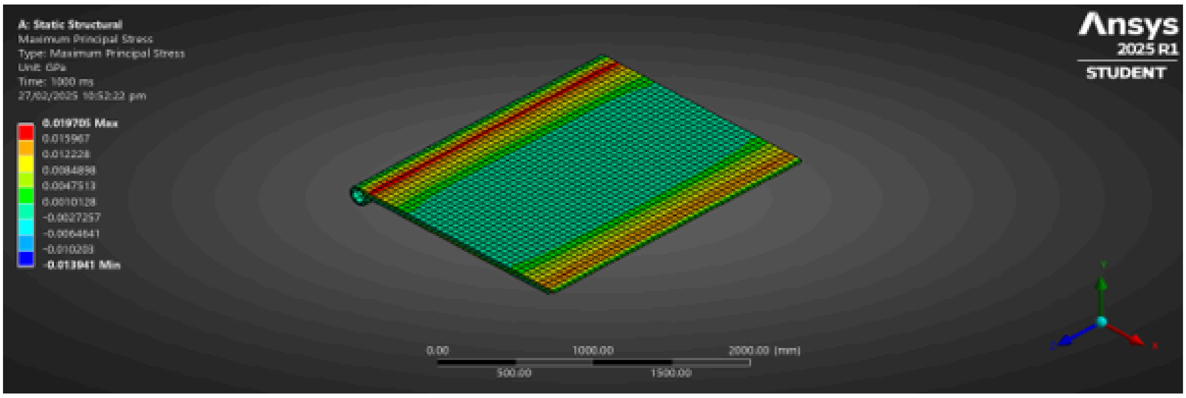
Source: *ANSYS Solution*

Figure 11
Axial Load Test - Ramp Deck

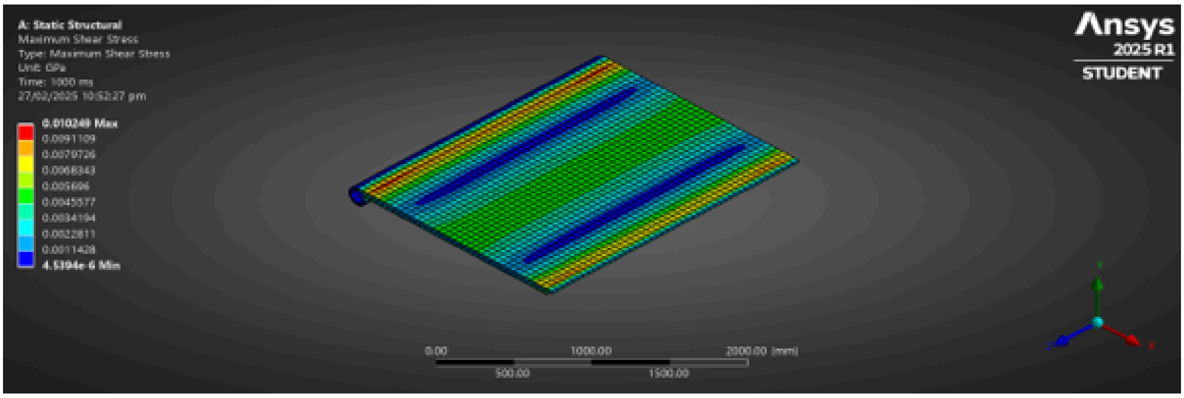
Total Deformation: 1.0819 mm



Maximum Principal Stress: 19.705 MPa



Maximum Shear Stress: 10.249 MPa



Source: *ANSYS Solution*

The data presented in Tables 5 and 6 show that the bridge and ramp decks passed the axial load test. The maximum principal stress and maximum shear stress values did not exceed the material's yield strength. It was proven that the thickness of each deck is adequate and safe for vehicle passage.

Design of Aluminum Bridge Shaft and Ramp Shaft

The shaft is the component that has a circular cross-section that connects the decks and the links. It provides support for rotating parts where the link and deck are mounted. It carries torque and withstands twisting forces. Moreover, it maintains the proper positioning of rotating parts and ensures smooth operation. The loads applied to test the shaft's maximum capacity and strength are axial loads. The shafts were designed with a diameter sufficient to carry all vehicle classes.

Table 7
Axial Load Test Result Summary - Bridge Shaft

VEHICLE CLASS	AXIAL LOAD (KN)	TOTAL DEFORMATION (mm)	MAXIMUM PRINCIPAL STRESS (MPa)	MAXIMUM SHEAR STRESS (MPa)	REMARKS
2	26.7224	0.60348	23.026	12.828	Passed
3	44.5374	1.0058	38.376	21.379	Passed
4	62.3523	1.4081	53.726	29.931	Passed
5	71.2598	1.6093	61.401	34.207	Passed
6	86.8479	1.9445	74.193	41.333	Passed
7	115.7972	2.5927	98.925	55.111	Passed
8	146.9734	3.2856	125.36	69.839	Passed

Source: *ANSYS Solution*

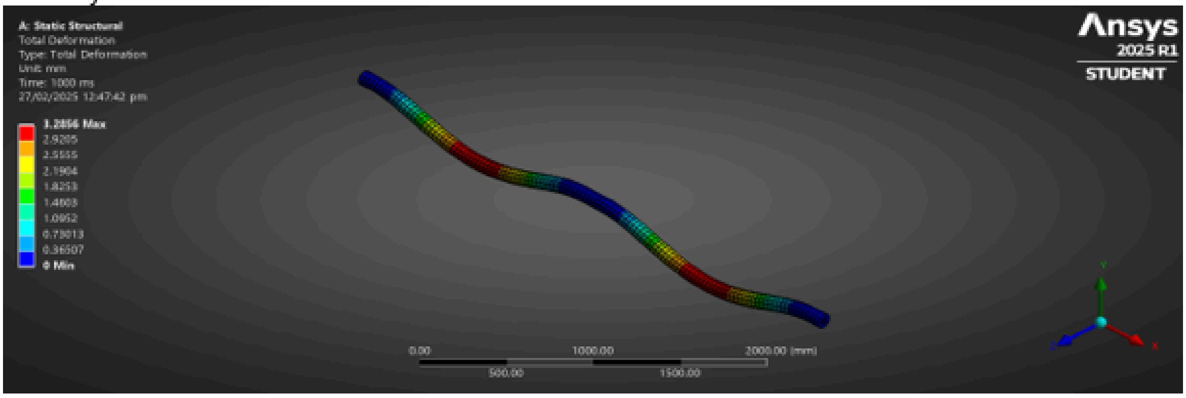
Table 8
Axial Load Test Result Summary - Ramp Shaft

VEHICLE CLASS	AXIAL LOAD (KN)	TOTAL DEFORMATION (mm)	MAXIMUM PRINCIPAL STRESS (MPa)	MAXIMUM SHEAR STRESS (MPa)	REMARKS
2	26.7224	1.5105	34.284	18.034	Passed
3	44.5374	2.5175	57.14	30.056	Passed
4	62.3523	3.5245	79.995	42.079	Passed
5	71.2598	4.0281	91.423	48.09	Passed
6	86.8479	4.8672	110.47	58.109	Passed
7	115.7972	6.4896	147.29	77.479	Passed
8	146.9734	8.2239	186.66	98.184	Passed

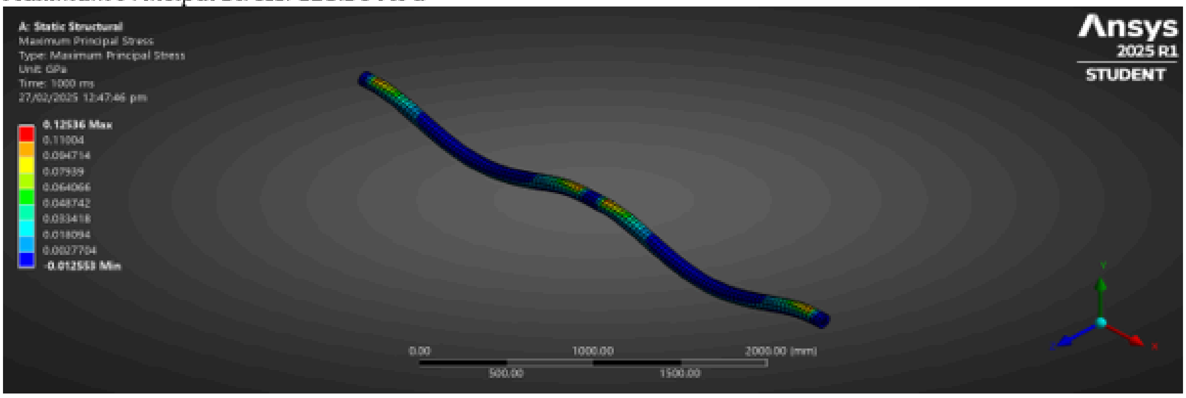
Source: *ANSYS Solution*

Figure 12
Axial Load Test - Bridge Shaft

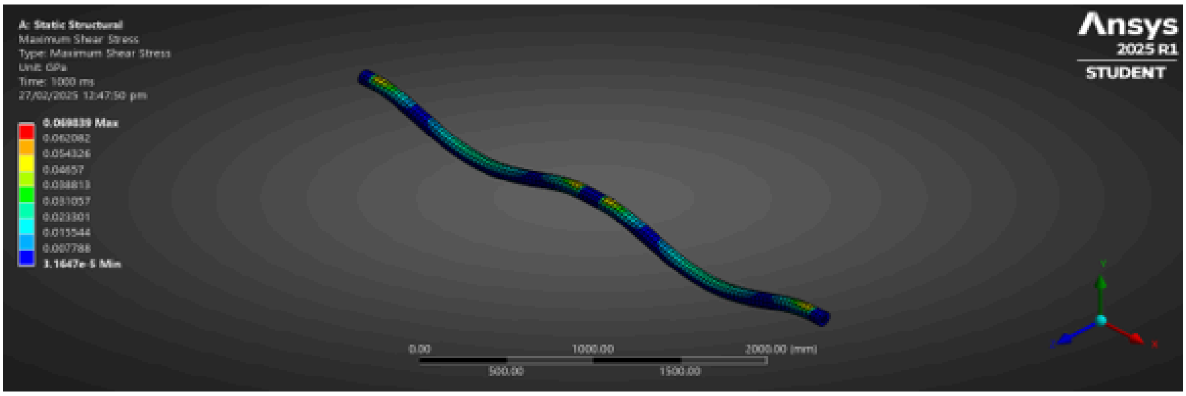
Total Deformation: 3.2856 mm



Maximum Principal Stress: 125.36 MPa



Maximum Shear Stress: 69.839 MPa



Source: *ANSYS Solution*

Summary of Quantities and Cost Estimation

The cost estimate presents the summary of quantities and the cost estimate for a single span of the bridge, the spans of the ramp, and the truss ramp.

Summary of Quantities and Cost Estimation - Single Span of Bridge

Table 9

	Parts of Bridge	Material	Quantity	Unit	Total Mass	Unit	Unit Price	Unit	Price
1	Deck	Aluminum	6	pcs	2851.1278	kg	₱155.05	₱/kg	₱442,058.31
2	Deck Extension	Aluminum	2	pcs	46.3008	kg	₱155.05	₱/kg	₱7,178.79
3	Link	Aluminum	24	pcs	1312.6207	kg	₱155.05	₱/kg	₱203,517.67
4	Shaft	Aluminum	6	pcs	578.0357	kg	₱155.05	₱/kg	₱89,622.60
5	Pin	Aluminum	12	pcs	26.5064	kg	₱155.05	₱/kg	₱4,109.73
6	Spacer	Aluminum	26	pcs	2.9413	kg	₱155.05	₱/kg	₱456.05
7	Circlip	Aluminum	66	pcs	0.7030	kg	₱155.05	₱/kg	₱109.00
8	Link Holder	Aluminum	6	pcs	56.9023	kg	₱155.05	₱/kg	₱8,822.53
9	Deck Bushing	Aluminum	18	pcs	33.8561	kg	₱155.05	₱/kg	₱5,249.29
10	Link Bushing	Aluminum	33	pcs	19.7230	kg	₱155.05	₱/kg	₱3,057.99
11	Railings	A36 Steel	2	set	105.4381	kg	₱54.60	₱/kg	₱5,756.92
12	Railings Plate	A36 Steel	4	pcs	29.1331	kg	₱54.60	₱/kg	₱1,590.67
	Support of Bridge	**Material**	**Quantity**	**Unit**	**Total Mass**	**Unit**	**Unit Price**	**Unit**	**Price**
1	Beam	A36 Steel	4	pcs	653.4167	kg	₱54.60	₱/kg	₱35,676.55
2	Column	A36 Steel	4	pcs	1053.6132	kg	₱54.60	₱/kg	₱57,527.28
3	Column Connection	A36 Steel	16	pcs	76.8672	kg	₱54.60	₱/kg	₱4,196.95
4	Column Plate	A36 Steel	4	pcs	49.3911	kg	₱54.60	₱/kg	₱2,696.75
5	Hydraulic Plate	A36 Steel	4	pcs	62.4056	kg	₱54.60	₱/kg	₱3,407.35
6	Span Connector	A36 Steel	2	pcs	28.1895	kg	₱54.60	₱/kg	₱1,539.14
7	20 Ton Hydraulic Jack		4	pcs			₱3,560.00	₱/pcs	₱14,240.00
8	Wheels		4	pcs			₱2,336.34	₱/pcs	₱9,345.34
					Total Mass	**Unit**	**Unit Price**	**Unit**	**Price**
1	Bolts High Tension				18	kg	₱141.12	₱/kg	₱2,540.16
2	3.2mm Welding Rod				73	kg	₱390.00	₱/5kg	₱5,694.00
				Total Mass	**6987.1716**	**kg**	Total Price		**₱908,393.07**

Summary of Quantities and Cost Estimation - 1st Ramp

Table 10

	Parts of 1st Ramp	Material	Quantity	Unit	Total Mass	Unit	Unit Price	Unit	Price
1	Deck	Aluminum	4	pcs	2242.1433	kg	₱155.05	₱/kg	₱347,637.20
2	Deck Extension	Aluminum	2	pcs	47.7493	kg	₱155.05	₱/kg	₱7,403.37
3	Link	Aluminum	16	pcs	884.9327	kg	₱155.05	₱/kg	₱137,206.00
4	Shaft	Aluminum	6	pcs	1674.9510	kg	₱155.05	₱/kg	₱259,695.83
5	Pin	Aluminum	6	pcs	15.0000	kg	₱155.05	₱/kg	₱2,325.70
6	Spacer	Aluminum	14	pcs	4.8090	kg	₱155.05	₱/kg	₱745.62
7	Circlip	Aluminum	24	pcs	1.4489	kg	₱155.05	₱/kg	₱224.65
8	Link Holder	Aluminum	6	pcs	161.2575	kg	₱155.05	₱/kg	₱25,002.47
9	Deck Bushing	Aluminum	8	pcs	290.7861	kg	₱155.05	₱/kg	₱45,085.47
10	Link Bushing	Aluminum	24	pcs	30.4875	kg	₱155.05	₱/kg	₱4,727.00
11	Railings	A36 Steel	2	set	93.9170	kg	₱54.60	₱/kg	₱5,127.87
12	Railings Plate	A36 Steel	4	pcs	29.1331	kg	₱54.60	₱/kg	₱1,590.67
	Support of 1st Ramp	**Material**	**Quantity**	**Unit**	**Total Mass**	**Unit**	**Unit Price**	**Unit**	**Price**
1	Beam	A36 Steel	4	pcs	893.2403	kg	₱54.60	₱/kg	₱48,770.92
2	Column	A36 Steel	4	pcs	1027.4359	kg	₱54.60	₱/kg	₱56,098.00
3	Column Connection	A36 Steel	16	pcs	76.8672	kg	₱54.60	₱/kg	₱4,196.95
4	Column Plate	A36 Steel	4	pcs	49.3911	kg	₱54.60	₱/kg	₱2,696.75
5	Hydraulic Plate	A36 Steel	4	pcs	62.4056	kg	₱54.60	₱/kg	₱3,407.35
6	Span Connector	A36 Steel	2	pcs	28.2303	kg	₱54.60	₱/kg	₱1,541.37
7	20 Ton Hydraulic Jack		4	pcs			₱3,560.00	₱/pcs	₱14,240.00
8	Wheels		4	pcs			₱2,336.34	₱/pcs	₱9,345.34
					Total Mass	**Unit**	**Unit Price**	**Unit**	**Price**
1	Bolts High Tension				20	kg	₱141.12	₱/kg	₱2,822.40
2	3.2mm Welding Rod				67	kg	₱390.00	₱/5kg	₱5,226.00
				Total Mass	**7614.1857**	**kg**	Total Price		**₱985,116.93**

Summary of Quantities and Cost Estimation – 2nd Ramp

Table 11

	Parts of 2nd Ramp	Material	Quantity	Unit	Total Mass	Unit	Unit Price	Unit	Price
1	Deck	Aluminum	4	pcs	2242.1433	kg	₱155.05	₱/kg	₱347,637.20
2	Deck Extension	Aluminum	2	pcs	47.7493	kg	₱155.05	₱/kg	₱7,403.37
3	Link	Aluminum	16	pcs	884.9327	kg	₱155.05	₱/kg	₱137,206.00
4	Shaft	Aluminum	6	pcs	1674.9510	kg	₱155.05	₱/kg	₱259,695.83
5	Pin	Aluminum	6	pcs	15.0000	kg	₱155.05	₱/kg	₱2,325.70
6	Spacer	Aluminum	14	pcs	4.8090	kg	₱155.05	₱/kg	₱745.62
7	Circlip	Aluminum	24	pcs	1.4489	kg	₱155.05	₱/kg	₱224.65
8	Link Holder	Aluminum	6	pcs	161.2575	kg	₱155.05	₱/kg	₱25,002.47
9	Deck Bushing	Aluminum	8	pcs	290.7861	kg	₱155.05	₱/kg	₱45,085.47
10	Link Bushing	Aluminum	24	pcs	30.4875	kg	₱155.05	₱/kg	₱4,727.00
11	Railings	A36 Steel	2	set	93.9170	kg	₱54.60	₱/kg	₱5,127.87
12	Railings Plate	A36 Steel	4	pcs	29.1331	kg	₱54.60	₱/kg	₱1,590.67
	Support of 2nd Ramp	**Material**	**Quantity**	**Unit**	**Total Mass**	**Unit**	**Unit Price**	**Unit**	**Price**
1	Beam	A36 Steel	4	pcs	893.2403	kg	₱54.60	₱/kg	₱48,770.92
2	Column	A36 Steel	4	pcs	975.0814	kg	₱54.60	₱/kg	₱53,239.45
3	Column Connection	A36 Steel	16	pcs	76.8672	kg	₱54.60	₱/kg	₱4,196.95
4	Column Plate	A36 Steel	4	pcs	49.3911	kg	₱54.60	₱/kg	₱2,696.75
5	Hydraulic Plate	A36 Steel	4	pcs	62.4056	kg	₱54.60	₱/kg	₱3,407.35
6	Span Connector	A36 Steel	2	pcs	28.2303	kg	₱54.60	₱/kg	₱1,541.37
7	20 Ton Hydraulic Jack		4	pcs			₱3,560.00	₱/pcs	₱14,240.00
8	Wheels		4	pcs			₱2,336.34	₱/pcs	₱9,345.34
					Total Mass	**Unit**	**Unit Price**	**Unit**	**Price**
1	Bolts High Tension				19	kg	₱141.12	₱/kg	₱2,681.28
2	3.2mm Welding Rod				67	kg	₱390.00	₱/5kg	₱5,226.00
				Total Mass	**7561.8312**	**kg**	Total Price		**₱982,117.25**

Summary of Quantities and Cost Estimation – 3rd Ramp

Table 12

	Parts of 3rd Ramp	Material	Quantity	Unit	Total Mass	Unit	Unit Price	Unit	Price
1	Deck	Aluminum	4	pcs	2242.1433	kg	₱155.05	₱/kg	₱347,637.20
2	Deck Extension	Aluminum	2	pcs	47.7493	kg	₱155.05	₱/kg	₱7,403.37
3	Link	Aluminum	16	pcs	884.9327	kg	₱155.05	₱/kg	₱137,206.00
4	Shaft	Aluminum	6	pcs	1674.9510	kg	₱155.05	₱/kg	₱259,695.83
5	Pin	Aluminum	6	pcs	15.0000	kg	₱155.05	₱/kg	₱2,325.70
6	Spacer	Aluminum	14	pcs	4.8090	kg	₱155.05	₱/kg	₱745.62
7	Circlip	Aluminum	24	pcs	1.4489	kg	₱155.05	₱/kg	₱224.65
8	Link Holder	Aluminum	6	pcs	161.2575	kg	₱155.05	₱/kg	₱25,002.47
9	Deck Bushing	Aluminum	8	pcs	290.7861	kg	₱155.05	₱/kg	₱45,085.47
10	Link Bushing	Aluminum	24	pcs	30.4875	kg	₱155.05	₱/kg	₱4,727.00
11	Railings	A36 Steel	2	set	93.9170	kg	₱54.60	₱/kg	₱5,127.87
12	Railings Plate	A36 Steel	4	pcs	29.1331	kg	₱54.60	₱/kg	₱1,590.67
	Support of 3rd Ramp	**Material**	**Quantity**	**Unit**	**Total Mass**	**Unit**	**Unit Price**	**Unit**	**Price**
1	Beam	A36 Steel	4	pcs	893.2403	kg	₱54.60	₱/kg	₱48,770.92
2	Column	A36 Steel	4	pcs	922.7269	kg	₱54.60	₱/kg	₱50,380.89
3	Column Connection	A36 Steel	16	pcs	76.8672	kg	₱54.60	₱/kg	₱4,196.95
4	Column Plate	A36 Steel	4	pcs	49.3911	kg	₱54.60	₱/kg	₱2,696.75
5	Hydraulic Plate	A36 Steel	4	pcs	62.4056	kg	₱54.60	₱/kg	₱3,407.35
6	Span Connector	A36 Steel	2	pcs	28.2303	kg	₱54.60	₱/kg	₱1,541.37
7	20 Ton Hydraulic Jack		4	pcs			₱3,560.00	₱/pcs	₱14,240.00
8	Wheels		4	pcs			₱2,336.34	₱/pcs	₱9,345.34
					Total Mass	**Unit**	**Unit Price**	**Unit**	**Price**
1	Bolts High Tension				19	kg	₱141.12	₱/kg	₱2,681.28
2	3.2mm Welding Rod				67	kg	₱390.00	₱/5kg	₱5,226.00
				Total Mass	**7509.4767**	**kg**	Total Price		**₱979,258.70**

Summary of Quantities and Cost Estimation – 4th Ramp

Table 13

	Parts of 4th Ramp	Material	Quantity	Unit	Total Mass	Unit	Unit Price	Unit	Price
1	Deck	Aluminum	4	pcs	2242.1433	kg	₱155.05	₱/kg	₱347,637.20
2	Deck Extension	Aluminum	2	pcs	47.7493	kg	₱155.05	₱/kg	₱7,403.37
3	Link	Aluminum	16	pcs	884.9327	kg	₱155.05	₱/kg	₱137,206.00
4	Shaft	Aluminum	6	pcs	1674.9510	kg	₱155.05	₱/kg	₱259,695.83
5	Pin	Aluminum	6	pcs	15.0000	kg	₱155.05	₱/kg	₱2,325.70
6	Spacer	Aluminum	14	pcs	4.8090	kg	₱155.05	₱/kg	₱745.62
7	Circlip	Aluminum	24	pcs	1.4489	kg	₱155.05	₱/kg	₱224.65
8	Link Holder	Aluminum	6	pcs	161.2575	kg	₱155.05	₱/kg	₱25,002.47
9	Deck Bushing	Aluminum	8	pcs	290.7861	kg	₱155.05	₱/kg	₱45,085.47
10	Link Bushing	Aluminum	24	pcs	30.4875	kg	₱155.05	₱/kg	₱4,727.00
11	Railings	A36 Steel	2	set	93.9170	kg	₱54.60	₱/kg	₱5,127.87
12	Railings Plate	A36 Steel	4	pcs	29.1331	kg	₱54.60	₱/kg	₱1,590.67
	Support of 4th Ramp	**Material**	**Quantity**	**Unit**	**Total Mass**	**Unit**	**Unit Price**	**Unit**	**Price**
1	Beam	A36 Steel	4	pcs	893.2403	kg	₱54.60	₱/kg	₱48,770.92
2	Column	A36 Steel	4	pcs	870.3724	kg	₱54.60	₱/kg	₱47,522.33
3	Column Connection	A36 Steel	16	pcs	76.8672	kg	₱54.60	₱/kg	₱4,196.95
4	Column Plate	A36 Steel	4	pcs	49.3911	kg	₱54.60	₱/kg	₱2,696.75
5	Hydraulic Plate	A36 Steel	4	pcs	62.4056	kg	₱54.60	₱/kg	₱3,407.35
6	Span Connector	A36 Steel	2	pcs	28.2303	kg	₱54.60	₱/kg	₱1,541.37
7	20 Ton Hydraulic Jack		4	pcs			₱3,560.00	₱/pcs	₱14,240.00
8	Wheels		4	pcs			₱2,336.34	₱/pcs	₱9,345.34
					Total Mass	**Unit**	**Unit Price**	**Unit**	**Price**
1	Bolts High Tension				18	kg	₱141.12	₱/kg	₱2,540.16
2	3.2mm Welding Rod				67	kg	₱390.00	₱/5kg	₱5,226.00
				Total Mass	**7457.1222**	**kg**	Total Price		**₱976,259.02**

Summary of Quantities and Cost Estimation – 5th Ramp

Table 14

	Parts of 5th Ramp	Material	Quantity	Unit	Total Mass	Unit	Unit Price	Unit	Price
1	Deck	Aluminum	4	pcs	2242.1433	kg	₱155.05	₱/kg	₱347,637.20
2	Deck Extension	Aluminum	2	pcs	47.7493	kg	₱155.05	₱/kg	₱7,403.37
3	Link	Aluminum	16	pcs	884.9327	kg	₱155.05	₱/kg	₱137,206.00
4	Shaft	Aluminum	6	pcs	1674.9510	kg	₱155.05	₱/kg	₱259,695.83
5	Pin	Aluminum	6	pcs	15.0000	kg	₱155.05	₱/kg	₱2,325.70
6	Spacer	Aluminum	14	pcs	4.8090	kg	₱155.05	₱/kg	₱745.62
7	Circlip	Aluminum	24	pcs	1.4489	kg	₱155.05	₱/kg	₱224.65
8	Link Holder	Aluminum	6	pcs	161.2575	kg	₱155.05	₱/kg	₱25,002.47
9	Deck Bushing	Aluminum	8	pcs	290.7861	kg	₱155.05	₱/kg	₱45,085.47
10	Link Bushing	Aluminum	24	pcs	30.4875	kg	₱155.05	₱/kg	₱4,727.00
11	Railings	A36 Steel	2	set	93.9170	kg	₱54.60	₱/kg	₱5,127.87
12	Railings Plate	A36 Steel	4	pcs	29.1331	kg	₱54.60	₱/kg	₱1,590.67
	Support of 5th Ramp	**Material**	**Quantity**	**Unit**	**Total Mass**	**Unit**	**Unit Price**	**Unit**	**Price**
1	Beam	A36 Steel	4	pcs	893.2403	kg	₱54.60	₱/kg	₱48,770.92
2	Column	A36 Steel	4	pcs	818.0179	kg	₱54.60	₱/kg	₱44,663.78
3	Column Connection	A36 Steel	16	pcs	76.8672	kg	₱54.60	₱/kg	₱4,196.95
4	Column Plate	A36 Steel	4	pcs	49.3911	kg	₱54.60	₱/kg	₱2,696.75
5	Hydraulic Plate	A36 Steel	4	pcs	62.4056	kg	₱54.60	₱/kg	₱3,407.35
6	Span Connector	A36 Steel	2	pcs	28.2303	kg	₱54.60	₱/kg	₱1,541.37
7	20 Ton Hydraulic Jack		4	pcs			₱3,560.00	₱/pcs	₱14,240.00
8	Wheels		4	pcs			₱2,336.34	₱/pcs	₱9,345.34
					Total Mass	**Unit**	**Unit Price**	**Unit**	**Price**
1	Bolts High Tension				18	kg	₱141.12	₱/kg	₱2,540.16
2	3.2mm Welding Rod				67	kg	₱390.00	₱/5kg	₱5,226.00
				Total Mass	**7404.7677**	**kg**	Total Price		**₱973,400.47**

Summary of Quantities and Cost Estimation – 6th Ramp

Table 15

	Parts of 6th Ramp	Material	Quantity	Unit	Total Mass	Unit	Unit Price	Unit	Price
1	Deck	Aluminum	4	pcs	2242.1433	kg	₱155.05	₱/kg	₱347,637.20
2	Deck Extension	Aluminum	2	pcs	47.7493	kg	₱155.05	₱/kg	₱7,403.37
3	Link	Aluminum	16	pcs	884.9327	kg	₱155.05	₱/kg	₱137,206.00
4	Shaft	Aluminum	6	pcs	1674.9510	kg	₱155.05	₱/kg	₱259,695.83
5	Pin	Aluminum	6	pcs	15.0000	kg	₱155.05	₱/kg	₱2,325.70
6	Spacer	Aluminum	14	pcs	4.8090	kg	₱155.05	₱/kg	₱745.62
7	Circlip	Aluminum	24	pcs	1.4489	kg	₱155.05	₱/kg	₱224.65
8	Link Holder	Aluminum	6	pcs	161.2575	kg	₱155.05	₱/kg	₱25,002.47
9	Deck Bushing	Aluminum	8	pcs	290.7861	kg	₱155.05	₱/kg	₱45,085.47
10	Link Bushing	Aluminum	24	pcs	30.4875	kg	₱155.05	₱/kg	₱4,727.00
11	Railings	A36 Steel	2	set	93.9170	kg	₱54.60	₱/kg	₱5,127.87
12	Railings Plate	A36 Steel	4	pcs	29.1331	kg	₱54.60	₱/kg	₱1,590.67
	Support of 6th Ramp	**Material**	**Quantity**	**Unit**	**Total Mass**	**Unit**	**Unit Price**	**Unit**	**Price**
1	Beam	A36 Steel	4	pcs	893.2403	kg	₱54.60	₱/kg	₱48,770.92
2	Column	A36 Steel	4	pcs	765.6634	kg	₱54.60	₱/kg	₱41,805.22
3	Column Connection	A36 Steel	16	pcs	76.8672	kg	₱54.60	₱/kg	₱4,196.95
4	Column Plate	A36 Steel	4	pcs	49.3911	kg	₱54.60	₱/kg	₱2,696.75
5	Hydraulic Plate	A36 Steel	4	pcs	62.4056	kg	₱54.60	₱/kg	₱3,407.35
6	Span Connector	A36 Steel	2	pcs	28.2303	kg	₱54.60	₱/kg	₱1,541.37
7	20 Ton Hydraulic Jack		4	pcs			₱3,560.00	₱/pcs	₱14,240.00
8	Wheels		4	pcs			₱2,336.34	₱/pcs	₱9,345.34
					Total Mass	**Unit**	**Unit Price**	**Unit**	**Price**
1	Bolts High Tension				17	kg	₱141.12	₱/kg	₱2,399.04
2	3.2mm Welding Rod				67	kg	₱390.00	₱/5kg	₱5,226.00
				Total Mass	**7352.4132**	**kg**	Total Price		**₱970,400.79**

Summary of Quantities and Cost Estimation – 7th Ramp

Table 16

	Parts of 7th Ramp	Material	Quantity	Unit	Total Mass	Unit	Unit Price	Unit	Price
1	Deck	Aluminum	4	pcs	2242.1433	kg	₱155.05	₱/kg	₱347,637.20
2	Deck Extension	Aluminum	2	pcs	47.7493	kg	₱155.05	₱/kg	₱7,403.37
3	Link	Aluminum	16	pcs	884.9327	kg	₱155.05	₱/kg	₱137,206.00
4	Shaft	Aluminum	6	pcs	1674.9510	kg	₱155.05	₱/kg	₱259,695.83
5	Pin	Aluminum	6	pcs	15.0000	kg	₱155.05	₱/kg	₱2,325.70
6	Spacer	Aluminum	14	pcs	4.8090	kg	₱155.05	₱/kg	₱745.62
7	Circlip	Aluminum	24	pcs	1.4489	kg	₱155.05	₱/kg	₱224.65
8	Link Holder	Aluminum	6	pcs	161.2575	kg	₱155.05	₱/kg	₱25,002.47
9	Deck Bushing	Aluminum	8	pcs	290.7861	kg	₱155.05	₱/kg	₱45,085.47
10	Link Bushing	Aluminum	24	pcs	30.4875	kg	₱155.05	₱/kg	₱4,727.00
11	Railings	A36 Steel	2	set	93.9170	kg	₱54.60	₱/kg	₱5,127.87
12	Railings Plate	A36 Steel	4	pcs	29.1331	kg	₱54.60	₱/kg	₱1,590.67
	Support of 7th Ramp	**Material**	**Quantity**	**Unit**	**Total Mass**	**Unit**	**Unit Price**	**Unit**	**Price**
1	Beam	A36 Steel	4	pcs	893.2403	kg	₱54.60	₱/kg	₱48,770.92
2	Column	A36 Steel	4	pcs	765.6634	kg	₱54.60	₱/kg	₱41,805.22
3	Column Connection	A36 Steel	16	pcs	76.8672	kg	₱54.60	₱/kg	₱4,196.95
4	Column Plate	A36 Steel	4	pcs	49.3911	kg	₱54.60	₱/kg	₱2,696.75
5	Hydraulic Plate	A36 Steel	4	pcs	62.4056	kg	₱54.60	₱/kg	₱3,407.35
6	Span Connector	A36 Steel	2	pcs	28.2303	kg	₱54.60	₱/kg	₱1,541.37
7	20 Ton Hydraulic Jack		4	pcs			₱3,560.00	₱/pcs	₱14,240.00
8	Wheels		4	pcs			₱2,336.34	₱/pcs	₱9,345.34
					Total Mass	**Unit**	**Unit Price**	**Unit**	**Price**
1	Bolts High Tension				17	kg	₱141.12	₱/kg	₱2,399.04
2	3.2mm Welding Rod				67	kg	₱390.00	₱/5kg	₱5,226.00
				Total Mass	**7352.4132**	**kg**	Total Price		**₱970,400.79**

Summary of Quantities and Cost Estimation – 8th Ramp

Table 17

	Parts of 8th Ramp	Material	Quantity	Unit	Total Mass	Unit	Unit Price	Unit	Price
1	Deck	Aluminum	4	pcs	2242.1433	kg	₱155.05	₱/kg	₱347,637.20
2	Deck Extension	Aluminum	2	pcs	47.7493	kg	₱155.05	₱/kg	₱7,403.37
3	Link	Aluminum	16	pcs	884.9327	kg	₱155.05	₱/kg	₱137,206.00
4	Shaft	Aluminum	6	pcs	1674.9510	kg	₱155.05	₱/kg	₱259,695.83
5	Pin	Aluminum	6	pcs	15.0000	kg	₱155.05	₱/kg	₱2,325.70
6	Spacer	Aluminum	14	pcs	4.8090	kg	₱155.05	₱/kg	₱745.62
7	Circlip	Aluminum	24	pcs	1.4489	kg	₱155.05	₱/kg	₱224.65
8	Link Holder	Aluminum	6	pcs	161.2575	kg	₱155.05	₱/kg	₱25,002.47
9	Deck Bushing	Aluminum	8	pcs	290.7861	kg	₱155.05	₱/kg	₱45,085.47
10	Link Bushing	Aluminum	24	pcs	30.4875	kg	₱155.05	₱/kg	₱4,727.00
11	Railings	A36 Steel	2	set	93.9170	kg	₱54.60	₱/kg	₱5,127.87
12	Railings Plate	A36 Steel	4	pcs	29.1331	kg	₱54.60	₱/kg	₱1,590.67
	Support of 8th Ramp	**Material**	**Quantity**	**Unit**	**Total Mass**	**Unit**	**Unit Price**	**Unit**	**Price**
1	Beam	A36 Steel	4	pcs	893.2403	kg	₱54.60	₱/kg	₱48,770.92
2	Column	A36 Steel	4	pcs	765.6634	kg	₱54.60	₱/kg	₱41,805.22
3	Column Connection	A36 Steel	16	pcs	76.8672	kg	₱54.60	₱/kg	₱4,196.95
4	Column Plate	A36 Steel	4	pcs	49.3911	kg	₱54.60	₱/kg	₱2,696.75
5	Hydraulic Plate	A36 Steel	4	pcs	62.4056	kg	₱54.60	₱/kg	₱3,407.35
6	Span Connector	A36 Steel	2	pcs	28.2303	kg	₱54.60	₱/kg	₱1,541.37
7	20 Ton Hydraulic Jack		4	pcs			₱3,560.00	₱/pcs	₱14,240.00
8	Wheels		4	pcs			₱2,336.34	₱/pcs	₱9,345.34
					Total Mass	**Unit**	**Unit Price**	**Unit**	**Price**
1	Bolts High Tension				17	kg	₱141.12	₱/kg	₱2,399.04
2	3.2mm Welding Rod				67	kg	₱390.00	₱/5kg	₱5,226.00
				Total Mass	**7352.4132**	**kg**	Total Price		**₱970,400.79**

Summary of Quantities and Cost Estimation – 9th Ramp

Table 18

	Parts of 9th Ramp	Material	Quantity	Unit	Total Mass	Unit	Unit Price	Unit	Price
1	Deck	Aluminum	4	pcs	2242.1433	kg	₱155.05	₱/kg	₱347,637.20
2	Deck Extension	Aluminum	2	pcs	47.7493	kg	₱155.05	₱/kg	₱7,403.37
3	Link	Aluminum	16	pcs	884.9327	kg	₱155.05	₱/kg	₱137,206.00
4	Shaft	Aluminum	6	pcs	1674.9510	kg	₱155.05	₱/kg	₱259,695.83
5	Pin	Aluminum	6	pcs	15.0000	kg	₱155.05	₱/kg	₱2,325.70
6	Spacer	Aluminum	14	pcs	4.8090	kg	₱155.05	₱/kg	₱745.62
7	Circlip	Aluminum	24	pcs	1.4489	kg	₱155.05	₱/kg	₱224.65
8	Link Holder	Aluminum	6	pcs	161.2575	kg	₱155.05	₱/kg	₱25,002.47
9	Deck Bushing	Aluminum	8	pcs	290.7861	kg	₱155.05	₱/kg	₱45,085.47
10	Link Bushing	Aluminum	24	pcs	30.4875	kg	₱155.05	₱/kg	₱4,727.00
11	Railings	A36 Steel	2	set	93.9170	kg	₱54.60	₱/kg	₱5,127.87
12	Railings Plate	A36 Steel	4	pcs	29.1331	kg	₱54.60	₱/kg	₱1,590.67
	Support of 9th Ramp	**Material**	**Quantity**	**Unit**	**Total Mass**	**Unit**	**Unit Price**	**Unit**	**Price**
1	Beam	A36 Steel	4	pcs	893.2403	kg	₱54.60	₱/kg	₱48,770.92
2	Column	A36 Steel	4	pcs	765.6634	kg	₱54.60	₱/kg	₱41,805.22
3	Column Connection	A36 Steel	16	pcs	76.8672	kg	₱54.60	₱/kg	₱4,196.95
4	Column Plate	A36 Steel	4	pcs	49.3911	kg	₱54.60	₱/kg	₱2,696.75
5	Hydraulic Plate	A36 Steel	4	pcs	62.4056	kg	₱54.60	₱/kg	₱3,407.35
6	Span Connector	A36 Steel	2	pcs	28.2303	kg	₱54.60	₱/kg	₱1,541.37
7	20 Ton Hydraulic Jack		4	pcs			₱3,560.00	₱/pcs	₱14,240.00
8	Wheels		4	pcs			₱2,336.34	₱/pcs	₱9,345.34
					Total Mass	**Unit**	**Unit Price**	**Unit**	**Price**
1	Bolts High Tension				17	kg	₱141.12	₱/kg	₱2,399.04
2	3.2mm Welding Rod				67	kg	₱390.00	₱/5kg	₱5,226.00
				Total Mass	**7352.4132**	**kg**	Total Price		**₱970,400.79**

Summary of Quantities and Cost Estimation - 1st Truss Ramp

Table 19

Parts of 1st Truss Ramp		Material	Quantity	Unit	Total Mass	Unit	Unit Price	Unit	Price
1	Top Members	A36 Steel	4	pcs	2433.0900	kg	₱54.60	₱/kg	₱132,846.71
2	Bottom Members	A36 Steel	4	pcs	2421.4669	kg	₱54.60	₱/kg	₱132,212.09
3	Web Members	A36 Steel	12	pcs	2367.9098	kg	₱54.60	₱/kg	₱129,287.87
4	Connetion	A36 Steel	8	pcs	1117.1034	kg	₱54.60	₱/kg	₱60,993.85
5	Deck	A36 Steel	2	pcs	10234.2648	kg	₱54.60	₱/kg	₱558,790.86
7	20 Ton Hydraulic Jack		4	pcs			₱3,560.00	₱/pcs	₱14,240.00
8	Wheels		4	pcs			₱2,336.34	₱/pcs	₱9,345.34
					Total Mass	**Unit**	**Unit Price**	**Unit**	**Price**
1	3.2mm Welding Rod				84	kg	₱390.00	₱/5kg	₱6,552.00
				Total Mass	**18573.8349**	**kg**	Total Price		**₱1,044,268.73**

Summary of Quantities and Cost Estimation – 2nd Truss Ramp

Table 20

Total Cost

Parts of 2nd Truss Ramp		Material	Quantity	Unit	Total Mass	Unit	Unit Price	Unit	Price
1	Top Members	A36 Steel	4	pcs	2433.0900	kg	Unit Price	Unit	₱132,846.71
2	Bottom Members	A36 Steel	4	pcs	2421.4669	kg	₱54.60	₱/kg	₱132,212.09
3	Web Members	A36 Steel	12	pcs	727.2314	kg	₱54.60	₱/kg	₱39,706.83
4	Connetion	A36 Steel	8	pcs	1117.1034	kg	₱54.60	₱/kg	₱60,993.85
5	Deck	A36 Steel	2	pcs	10234.2648	kg	₱54.60	₱/kg	₱558,790.86
7	20 Ton Hydraulic Jack		4	pcs			₱3,560.00	₱/pcs	₱14,240.00
8	Wheels		4	pcs			₱2,336.34	₱/pcs	₱9,345.34
					Total Mass	**Unit**	**Unit Price**	**Unit**	**Price**
1	3.2mm Welding Rod				67	kg	₱390.00	₱/5kg	₱5,226.00
				Total Mass	**16933.1565**	**kg**	Total Price		**₱953,361.69**

Estimation for 1 Set of MFOB Ramp

Table 21

Parts of 1 Set of MFOB Ramp		Price
1	1st Ramp	₱985,116.93
2	2nd Ramp	₱982,117.25
3	3rd Ramp	₱979,258.70
4	4th Ramp	₱976,259.02
5	5th Ramp	₱973,400.47
6	6th Ramp	₱970,400.79
7	7th Ramp	₱970,400.79
8	8th Ramp	₱970,400.79
9	9th Ramp	₱970,400.79
10	1st Truss Ramp	₱1,044,268.73
11	2nd Truss Ramp	₱953,361.69
Total Price of 1 Set of MFOB Ramp		**₱10,775,385.95**

CONCLUSION AND RECOMMENDATIONS

Conclusion

The study designed and analyzed a Mobile FlyOver Bridge (MFOB) to maintain continuous traffic flow and reduce congestion during road construction. It aimed to use steel as the primary material, evaluate the load capacity, provide a mobilization and demobilization scheme, and provide a detailed cost estimate for the MFOB. After a thorough analysis and review of the results of the study, the simulations, and a detailed cost estimation, the following conclusions are drawn:

1. The two materials used in the study, the aluminum alloy (A2024) and A36 steel, were validated through load testing. The aluminum alloy (A2024), having a yield strength of 363 MPa, has been proven as a highly suitable material for retractable structures due to its high strength and lightweight properties. The A36 steel, with a yield strength of 248 MPa, was also adequate for the truss ramp and the retractable columns and beams.
2. The MFOB's initial parameters were revised to achieve an optimal and safe design that fulfills its intended function. The final design features a length of 5.55 meters, a width of 4.35 meters, and a total height of 5.27 meters from the floor line to the deck surface. It provides a vertical clearance of 4.12 meters from the floor line to the bottom of the beam and a horizontal clearance of 3.60 meters, ensuring safe passage for vehicles. Additionally, the designed ramp has a total length of 60.53 meters and follows a slope of 1:12.
3. Through structural analysis using STAAD Pro and ANSYS, the MFOB demonstrated the capacity to safely accommodate vehicles across all weight classes and categories, having a maximum load capacity of 76.1411 tons. The load testing showed that the designed structural components and their assembled configuration produced reliable results, with the maximum principal and shear stress remaining within the yield strengths of aluminum alloy (A2024) and A36 steel. The deformations were minimal and considered safe. The results of the load testing conducted ensure the structure's safety and durability under expected loading conditions.
4. A comprehensive mobilization and demobilization scheme for the MFOB was developed. The process included the coordinated use of workforce and equipment, such as trailer trucks and mobile cranes, for transportation and assembly. A detailed sequence of assembly and disassembly was provided, outlining the systematic process that enables efficient deployment while minimizing traffic disruptions.
5. The total estimated cost of the MFOB, including a set of ramps and a single bridge span, is ₱11,683,779.02. This cost shows that the MFOB is a viable solution. Additionally, the portability and reusability of the MFOB make it a cost-effective and practical alternative for managing traffic during road reblocking and construction projects.

Recommendations

Based on the findings and analysis of the MFOB, the researchers forward these recommendations to enhance the bridge's design and functionality. These recommendations aim to address identified limitations, improve operational efficiency, and guide future research:

1. The initial design was limited to straight-road sections to validate the study's feasibility and establish a foundation for designing a more complex configuration. Given the Philippines' extensive mountainous highways, developing a design suitable for curved roads presents a promising area for future research.
2. The study incorporated systems and mechanisms, but only included them in the structure, describing their functions as they fell beyond the researchers' design capabilities. The development of a hydraulic or pneumatic system to enable the expansion and retraction of the bridge's scissor structure, as well as the integration of a similar system for the columns to allow adjustable height and faster deployment, presents a valuable opportunity for future research. The wheels must also be designed to have adequate capacity to carry the bridge, and the centralized controls for mobility shall be designed for them to be moved all at once.
3. The length of each span of the bridge can be increased. Increasing the bridge span could reduce the number of spans required for transportation and assembly, improving overall efficiency.
4. Fatigue due to temperature and dynamic loading was not considered in the design of MFOB. Future research must include it in the analysis to further improve the design.

5. To expand the applicability and effectiveness of the MFOB, future research should focus on enhancing the MFOB for deployment in flood-prone areas and as a temporary bridge during natural disasters such as earthquakes, landslides, and typhoons.
6. To accurately assess the feasibility of the MFOB, a comprehensive cost analysis should be conducted.

By implementing these recommendations, the MFOB can be further optimized to better serve as a practical solution for minimizing traffic congestion during road construction.

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