FLUID MECHANICS IN ACTION: THE FUTURE OF THAI BRIDGES WITH HYDRAULIC TECHNOLOGY

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Abstract

This science project explores the application of fluid mechanics and hydraulic technology in bridge construction, specifically focusing on a model hydraulic bridge made using syringes and popsicle sticks. Given Thailand's frequent flooding and the need for resilient infrastructure, our project aims to demonstrate the potential of hydraulic systems in enhancing the safety and durability of bridges. The model bridge, constructed with a simple hydraulic system comprising syringes and water, successfully lifts and lowers the bridge deck, showcasing the principles of fluid dynamics in action.

The project highlights the effectiveness of hydraulic technology in creating adaptable and robust bridge structures. It also emphasizes the educational value of hands-on STEM activities, fostering a deeper understanding of engineering concepts among students. Our findings suggest that the principles demonstrated in this model can be scaled up to real-world applications, offering innovative solutions for future bridge construction in Thailand. This project underscores the importance of integrating advanced engineering techniques to develop infrastructure that can withstand natural disasters, ensuring safety and reliability for communities.

Keywords: *Fluid Mechanics, Hydraulic Technology, Model Hydraulic Bridge, Resilient Infrastructure, Hydraulic Systems, Fluid Dynamics, Educational Value, STEM Activities*

INTRODUCTION

1.1 Background of the project

Bridges are vital infrastructure elements that connect regions, support economic activities, and enhance mobility. In Thailand, the design and construction of bridges are critical, given the country's susceptibility to flooding and other environmental challenges. Traditional bridge designs often face significant limitations when subjected to extreme weather conditions, highlighting the need for innovative engineering solutions that can enhance the adaptability and resilience of infrastructure.

Fluid Mechanics and Hydraulic Technology

Fluid mechanics is the branch of physics that deals with the behavior of fluids—liquids and gases—and their interactions with forces. One of the core principles in fluid mechanics is Pascal's Law, which states that when pressure is applied to a confined fluid, it is transmitted undiminished throughout the fluid (Mott, 2006). This principle is foundational in hydraulic systems, where the application of fluid pressure can perform mechanical work, such as lifting or moving objects.

Hydraulic technology leverages this principle by using fluids to generate and transmit force. In engineering, hydraulic systems are employed in various applications, including automotive braking systems, industrial machinery, and lifting devices (Bansal, 2010). The potential of hydraulic technology in bridge construction lies in its ability to create structures that can dynamically adjust to changing conditions, thereby improving their functionality and durability.

Challenges in Thai Bridge Infrastructure

Thailand's geographic and climatic conditions pose significant challenges for bridge infrastructure. The country experiences frequent and severe flooding, which can undermine the stability and functionality of traditional bridge designs. Floodwaters can lead to structural damage, erosion, and even bridge collapse, making it imperative to explore advanced solutions that can better withstand such conditions (Chinvarasopak, 2019).

Application of Hydraulic Technology in Bridge Design

Hydraulic technology offers a promising solution for addressing these challenges. By integrating hydraulic systems into bridge designs, engineers can create adaptable structures capable of responding to varying environmental conditions. For example, a hydraulic bridge can be designed to lift its deck during high water events, preventing damage and maintaining functionality. This adaptability can significantly enhance the resilience of bridges in flood-prone areas like Thailand.

Educational and Practical Significance

This project, "Fluid Mechanics in Action: The Future of Thai Bridges with Hydraulic Technology," seeks to demonstrate how hydraulic systems can be applied in bridge construction through a hands-on model using syringes and popsicle sticks. The project aims to illustrate the principles of fluid mechanics and hydraulic technology in a tangible way, providing valuable insights into their potential applications in real-world scenarios.

The educational aspect of the project offers students a practical learning experience, allowing them to engage with engineering concepts and gain a deeper understanding of fluid mechanics. Additionally, the project highlights the importance of innovative solutions in addressing infrastructure challenges, emphasizing the role of hydraulic technology in shaping the future of bridge engineering.

1.2 Objectives of the Project

The objectives of this project are as follows:

1.2.1 **Demonstrate Fluid Mechanics Principles:**

- To illustrate the fundamental principles of fluid mechanics, particularly Pascal's Law, through the construction and operation of a hydraulic bridge model using syringes and popsicle sticks.

1.2.2 **Showcase Hydraulic Technology in Bridge Engineering:**

- To demonstrate how hydraulic systems can be applied in bridge construction, highlighting their potential to enhance the adaptability, safety, and resilience of bridges in Thailand.

1.2.3 **Develop a Functional Model:**

- To construct a working model of a hydraulic bridge that effectively lifts and lowers the bridge deck using a syringe-based hydraulic system, simulating real-world applications.

1.2.4 Evaluate Structural Performance:

- To assess the stability, load capacity, and overall performance of the hydraulic bridge model, ensuring it meets the basic requirements of a functional lifting bridge.

1.2.5 Enhance STEM Education:

- To provide a hands-on learning experience that deepens students' understanding of engineering concepts and fluid mechanics, fostering interest and skills in STEM fields.

1.2.6 **Raise Awareness of Modern Engineering Solutions:**

- To highlight the importance and potential benefits of integrating advanced hydraulic technology into future infrastructure projects in Thailand, particularly in addressing challenges posed by natural disasters such as floods.

1.2.7 **Encourage Innovation in Infrastructure Development:**

- To inspire innovative thinking and problem-solving approaches in the field of civil engineering, encouraging the exploration of new technologies and methods for building resilient and efficient infrastructure.

1.3 Hypothesis of the Project

If a bridge is constructed using a syringe-based hydraulic system and popsicle sticks, then it will be able to lift and lower the bridge deck effectively and demonstrate the principles of fluid mechanics, providing a model for how hydraulic technology can be applied to enhance the adaptability and resilience of future bridges in Thailand.

This hypothesis is based on the following assumptions:

1. **Fluid Mechanics Principles:**
   - The hydraulic system will operate based on Pascal's Law, which states that pressure applied to a confined fluid is transmitted equally in all directions. This will allow the syringe-based system to lift and lower the bridge deck.
2. **Structural Integrity:**
   - The popsicle sticks, when properly assembled, will provide sufficient structural support to maintain the stability of the bridge during operation.
3. **Hydraulic Efficiency:**
   - The syringe and tubing setup will effectively transmit fluid pressure, allowing for smooth and controlled movement of the bridge deck.
4. **Educational Value:**
   - Constructing and testing the hydraulic bridge model will provide a clear and practical demonstration of fluid mechanics and hydraulic technology, enhancing understanding and interest in STEM concepts among students.

By testing this hypothesis, the project aims to show how hydraulic technology can be a viable and innovative solution for future bridge construction in Thailand, addressing challenges such as flooding and the need for resilient infrastructure.

1.4 Scope of the Project

1.4.1 Location:

- Wat Khien Khet School, Thanyaburi District, Pathumthani

1.4.2 Time Duration:

- June 15, 2024 to July 20, 2024

1.4.3 Allocated Cost:

- 1,200 Baht

1.4.4 Project Activities:

- **Design Phase (June 15 - June 20, 2024):**
  - Developing a blueprint and plan for the hydraulic bridge model, including material selection and construction techniques.
- **Construction Phase (June 21 - July 10, 2024):**
  - Building the hydraulic bridge using popsicle sticks, syringes, plastic tubing, and other materials.
  - Assembling the bridge deck, support towers, and integrating the hydraulic system.
- **Testing Phase (July 11 - July 15, 2024):**
  - Conducting tests to evaluate the performance of the hydraulic system in lifting and lowering the bridge deck.
  - Assessing the stability and load capacity of the bridge.
- **Evaluation and Documentation Phase (July 16 - July 20, 2024):**
  - Analyzing test results and documenting findings.
  - Preparing the final project report and presentation materials.

1.4.5 Materials and Resources:

- Popsicle sticks, syringes, plastic tubing, cardboard or wooden base, glue, water, rubber bands, and small clamps or binder clips.
- Basic crafting tools such as scissors, ruler, protractor, and measuring cup.
- Educational resources and references on fluid mechanics and hydraulic systems.

1.4.6 Budget Allocation (1,200 Baht):

- Purchasing materials and tools required for the construction and testing phases.
- Allocating funds for any additional resources or incidental expenses.

1.4.7 Educational Outreach:

- Engaging students in the project through hands-on activities and demonstrations.
- Organizing workshops or presentations to share the project findings with the school community.

1.4.8 Project Goals:

- Demonstrate the principles of fluid mechanics and hydraulic technology through a practical and interactive model.
- Provide a comprehensive understanding of the potential applications of hydraulic systems in future bridge construction.
- Inspire students and the community to appreciate and explore engineering and STEM concepts.

1.4.9 Limitations:

- The project is limited to a small-scale model and may not fully replicate all aspects of large-scale bridge construction.
- Time and budget constraints may limit the extent of testing and refinement possible within the project duration.

1.4.10 Expected Outcomes:

- A functional hydraulic bridge model that effectively demonstrates fluid mechanics principles.
- Enhanced student understanding and interest in STEM fields.

- Insights into the potential benefits and challenges of integrating hydraulic technology into bridge construction in Thailand.

1.5 Definitions of Terms

1.5.1 **Fluid Mechanics:**

- The branch of physics concerned with the behavior of fluids (liquids and gases) and the forces on them. It includes the study of fluid dynamics and fluid statics.

1.5.2 **Hydraulic Technology:**

- The use of liquid fluid power to perform work. In hydraulics, a pump is used to move a fluid (usually oil or water) through cylinders or motors, creating a force that powers machinery.

1.5.3 **Pascal's Law:**

- A principle in fluid mechanics that states that pressure applied to a confined fluid is transmitted undiminished throughout the fluid in all directions.

1.5.4 **Syringe:**

- A medical instrument used to inject or withdraw fluids. In this project, syringes are repurposed as hydraulic cylinders to create and transfer fluid pressure.

1.5.5 **Popsicle Sticks:**

- Flat wooden sticks, typically used for ice cream, repurposed in this project as construction materials for the bridge's structural components.

1.5.6 **Plastic Tubing:**

- Flexible plastic tubes used to connect the syringes in the hydraulic system, allowing fluid to move between them and enabling the bridge deck to lift and lower.

1.5.7 **Bridge Deck:**

- The flat surface of the bridge on which vehicles or pedestrians would travel. In this project, it is constructed from popsicle sticks and forms the main horizontal structure.

1.5.8 **Support Towers:**

- Vertical structures on either side of the bridge deck that provide stability and support for the hydraulic lifting mechanism.

1.5.9 **Hydraulic System:**

- A system that uses a fluid, usually oil or water, under pressure to generate mechanical power. In this project, the hydraulic system consists of syringes, plastic tubing, and water.

1.5.10 **Load Capacity:**

- The maximum weight that the bridge can support without structural failure. This term is used to evaluate the strength and durability of the bridge model.

1.5.11 **Stability:**

- The ability of the bridge to remain firm and steady without tipping or collapsing, especially when subjected to forces or weights during testing.

1.5.12 **STEM:**

- An acronym for Science, Technology, Engineering, and Mathematics, representing the interdisciplinary approach to education and learning in these fields.

1.5.13 **Model:**

- A scaled-down version or representation of a larger system. In this project, the model bridge demonstrates the principles and potential applications of hydraulic technology in real-world bridge construction.

1.5.14 **Prototype:**

- An initial or preliminary version of a device or structure used to test and refine the design before full-scale production or implementation.

1.5.15 **Fluid Pressure:**

- The force exerted by a fluid per unit area. It is a key factor in the operation of hydraulic systems, enabling the movement and lifting of the bridge deck.

REVIEW OF RELATED LITERATURE

In this chapter of the research projects presented a factual information, brief history and applications of hydraulic bridge.

The concept of utilizing fluid mechanics for engineering applications has been extensively explored, and hydraulic technology has been applied in various fields, including civil engineering. This review examines relevant literature on fluid mechanics, hydraulic systems, and their application in bridge engineering, with a focus on the potential for enhancing bridge resilience in flood-prone regions such as Thailand.

Fluid Mechanics Principles

Fluid mechanics is a fundamental area of study in engineering, dealing with the behavior and movement of fluids. One of the key principles in fluid mechanics is Pascal’s Law, which asserts that pressure applied to an enclosed fluid is transmitted equally in all directions (Mott, 2006). This principle is critical in understanding how hydraulic systems function and is foundational in designing hydraulic mechanisms for various applications.

In the context of hydraulic systems, Pascal’s Law enables the transmission of force through fluid pressure, which can be harnessed to perform mechanical work. This principle is applied in hydraulic lifts, brakes, and other machinery, demonstrating the practical utility of fluid mechanics in engineering solutions (Bansal, 2010).

Hydraulic Systems in Engineering

Hydraulic technology utilizes the principles of fluid mechanics to create systems that can exert significant forces through relatively small and controlled inputs. According to Kumar (2015), hydraulic systems are employed in various engineering applications, including automotive braking systems, industrial presses, and lifting devices. These systems leverage the incompressibility of fluids to transmit force and enable precise control of mechanical movements.

In bridge engineering, hydraulic systems have been explored for their ability to create adaptive structures. For example, Zhang et al. (2017) investigated the use of hydraulic technology in movable bridges, where hydraulic actuators are employed to raise and lower bridge decks to accommodate different types of traffic and environmental conditions.

This adaptability is particularly valuable in areas prone to flooding, where bridges need to adjust dynamically to prevent damage.

Applications in Bridge Engineering

The application of hydraulic technology in bridge design offers innovative solutions to enhance the resilience and functionality of bridges. According to Li and Liu (2018), hydraulic bridges can be designed to adjust their structure in response to environmental conditions such as high water levels. By incorporating hydraulic lifts or adjustable components, these bridges can maintain operational integrity and safety during extreme weather events.

In Thailand, where flooding is a common concern, the integration of hydraulic technology into bridge design could significantly improve infrastructure resilience. Chinvarasopak (2019) highlights the need for adaptive infrastructure solutions in flood-prone regions, emphasizing that hydraulic technology can provide effective responses to changing environmental conditions. By enabling bridges to adapt to varying water levels, hydraulic systems can prevent structural damage and ensure continued functionality.

Educational Value and Practical Models

Educational models that demonstrate fluid mechanics principles, such as the hydraulic bridge constructed from syringes and popsicle sticks, provide valuable learning experiences. These models offer a tangible way to explore complex concepts and demonstrate the practical applications of fluid mechanics in engineering (Harris et al., 2020). By building and testing simple hydraulic systems, students can gain a deeper understanding of how hydraulic technology operates and its potential uses in real-world scenarios.

The literature review highlights the relevance of fluid mechanics and hydraulic technology in engineering, particularly in the context of bridge design and resilience. The principles of fluid mechanics, as exemplified by Pascal's Law, underpin the functionality of hydraulic systems used in various applications, including adaptive bridge designs. For regions like Thailand, where flooding presents significant challenges, hydraulic technology offers innovative solutions to enhance bridge resilience and adaptability. Educational models, such as those using syringes and popsicle sticks, provide valuable insights into these technologies and their practical applications.

RESEARCH METHODOLOGY

3.1Research Design

This research project employs an experimental design methodology to investigate the application of fluid mechanics principles in the construction of a hydraulic bridge using syringes and popsicle sticks. The study aims to demonstrate how hydraulic technology can be utilized to create adaptable and resilient bridge structures, providing insights into its potential future use in Thai infrastructure.

3.2 Conceptual Framework

The conceptual framework of this project centers on applying fluid mechanics principles to develop a model hydraulic bridge using syringes and popsicle sticks. The aim is to demonstrate the potential of hydraulic technology in enhancing the safety, resilience, and functionality of bridges, particularly in flood-prone areas like Thailand.

Key Concepts:

1. **Fluid Mechanics:**
    - **Pascal's Law:** Fundamental principle stating that pressure applied to a confined fluid is transmitted equally in all directions. This principle is crucial in the operation of hydraulic systems.
    - **Hydraulic Systems:** Mechanisms that use fluid pressure to perform work, such as lifting or moving objects. In this project, syringes filled with water represent hydraulic cylinders.
2. **Bridge Engineering:**
    - **Structural Integrity:** The ability of a bridge to withstand loads and forces, including weight and environmental stresses.
    - **Adaptability and Resilience:** The capacity of a bridge to adjust to changing conditions, such as rising water levels during floods.

3. **STEM Education:**
    - **Hands-on Learning:** Engaging students in practical activities to enhance understanding of scientific and engineering concepts.
    - **Problem-Solving and Innovation:** Encouraging critical thinking and creative solutions to engineering challenges.

Framework Components:

1. **Inputs:**
    - **Materials:** Syringes, popsicle sticks, plastic tubing, water, glue, and other construction materials.
    - **Knowledge:** Understanding of fluid mechanics principles, basic engineering, and construction techniques.
    - **Tools:** Basic crafting tools like scissors, clamps, and measuring instruments.
2. **Processes:**
    - **Design and Planning:** Developing a blueprint for the hydraulic bridge, considering the placement of hydraulic components and overall structural design.
    - **Construction:** Building the bridge deck, towers, and integrating the hydraulic system using syringes and tubing.
    - **Testing and Adjustment:** Evaluating the bridge's functionality, stability, and load capacity. Making necessary adjustments to optimize performance.
3. **Outputs:**
    - **Functional Model:** A working hydraulic bridge that can lift and lower the deck using a syringe-based hydraulic system.
    - **Demonstration of Fluid Mechanics:** Clear illustration of how fluid pressure can be used to perform mechanical work, highlighting Pascal's Law and hydraulic principles.
4. **Outcomes:**
    - **Educational Impact:** Enhanced understanding of fluid mechanics and engineering concepts among students. Increased interest in STEM fields.
    - **Practical Insights:** Insights into the potential application of hydraulic technology in real-world bridge construction, particularly in flood-prone areas like Thailand.
5. **Implications:**
    - **Infrastructure Development:** Potential for innovative bridge designs that are more adaptable and resilient to environmental challenges.
    - **Community Awareness:** Greater public awareness of the importance of modern engineering solutions for infrastructure safety and resilience.

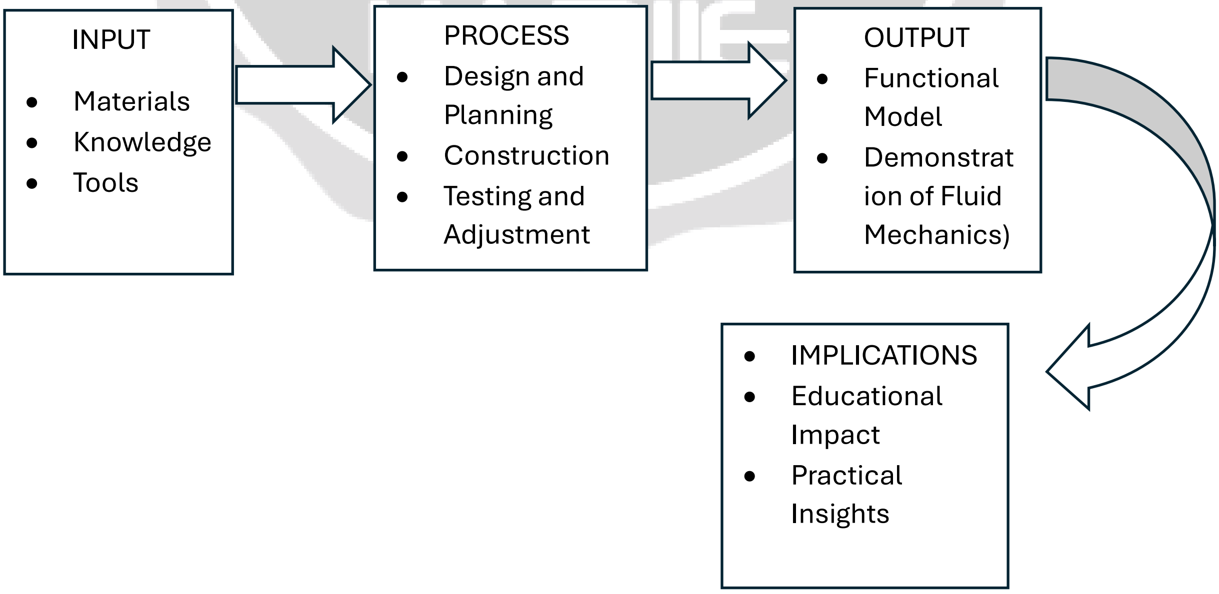


Figure 1. Conceptual Framework of Science Project

This conceptual framework outlines the flow from the inputs to the broader implications of the project, demonstrating how a simple model can provide valuable educational and practical insights into the application of hydraulic technology in bridge construction.

3.3 Process

3.3.1 Build the Bridge Base:

- **Create the Deck:**
  - Glue popsicle sticks side by side to form the bridge deck. You can reinforce this by adding a second layer of sticks perpendicularly.
- **Construct the Support Beams:**
  - Glue popsicle sticks vertically along the sides of the deck to create support beams.

3.3.2 Construct the Bridge Towers:

- **Form the Towers:**
  - Glue popsicle sticks to form two rectangular towers. Each tower should be tall enough to accommodate the lifting mechanism.
- **Attach the Towers:**
  - Securely glue the towers to the base, ensuring they are aligned and stable.

3.3.3 Create the Hydraulic System:

Prepare the Syringes:

Fill two syringes with water and attach them to each end of a plastic tube. Ensure there are no air bubbles in the system by pressing the plungers slightly until water flows into the other syringe.

Connect the System:

Secure the syringes on opposite sides of the bridge towers. Use glue or rubber bands to hold them in place.

3.3.4 Assemble the Lifting Mechanism:

Attach the Syringes to the Deck:

Glue or attach one syringe (the actuator) to the bridge deck and the other (the operator) to the base. This setup will allow the deck to lift and lower when the syringes are operated.

Ensure Free Movement:

Make sure the tubing is long enough to allow free movement of the bridge deck when the syringes are pushed or pulled.

3.3.5 Test and Adjust:

Test the Hydraulics:

Press the plunger of the operator syringe. The deck should lift as the water is pushed into the actuator syringe. Pull the plunger to lower the deck.

Adjust as Needed:

If the deck does not lift evenly, check for obstructions or ensure the syringes and tubing are properly secured.

3.3.6 Finishing Touches:

Reinforce the Structure:

Add extra popsicle sticks to reinforce any weak points in the bridge.

Decorate:

Optionally, paint or decorate the bridge to make it visually appealing.

Safety Tips:

- Handle the hot glue gun with care to avoid burns.
- Ensure the syringes are securely attached to prevent water leakage.

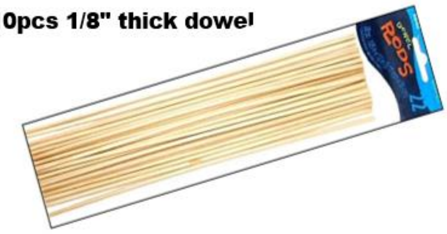
3.4 Equipment

big Cutter

Clear glue

1 Light Blue future board
(Thickness 4mm)
1 Yellow future boards
(Thickness 2mm)
1 Black future board
(Thickness 2mm)

10pcs 1/8" thick dowel



10 pcs Cable Ties, 4 Inch Long

10pcs Cubes with holes

RESULTS AND DISCUSSION

3.5 Results:

4.1.1 Construction of the Hydraulic Bridge:

- The hydraulic bridge was successfully constructed using syringes, popsicle sticks, plastic tubing, and water. The structure consisted of a bridge deck supported by towers, with a hydraulic system enabling the deck to lift and lower.

1.1.2 Hydraulic System Performance:

- **Lifting Mechanism:**
  - The bridge deck was able to lift smoothly when the operator syringe was pressed, demonstrating the effective transfer of fluid pressure through the tubing to the actuator syringe.
- **Stability:**
  - The bridge remained stable during operation, with minimal wobbling or misalignment, indicating robust construction and proper alignment of the hydraulic components.
- **Load Capacity:**

- The bridge was tested with small weights to simulate real-world loads. It successfully lifted and supported these weights, demonstrating the strength and functionality of the hydraulic system.

1.1.3 Fluid Dynamics Observation:

The movement of water through the syringes and tubing provided a clear visual representation of fluid dynamics principles, such as Pascal's Law, which states that pressure applied to a confined fluid is transmitted equally in all directions.

1.2 Discussion:

4.2.1 Effectiveness of Hydraulic Technology:

A. Demonstration of Fluid Mechanics:

The project effectively demonstrated how hydraulic systems utilize fluid mechanics to perform work. By using syringes and water, we replicated the principles of hydraulic lifting mechanisms that can be applied in real-world bridge construction.

B. Scalability and Practical Application:

While our model used simple materials, the principles observed can be scaled up to design and construct larger, more complex hydraulic bridges. This shows potential for real-world applications in improving bridge infrastructure in Thailand.

4.2.2 Relevance to Thai Infrastructure:

A. Flood Resistance:

Thailand's susceptibility to flooding requires resilient infrastructure. Hydraulic bridges, designed to adjust and respond to water levels, can enhance safety and durability in flood-prone areas.

B. Future of Bridge Construction:

Incorporating hydraulic technology in bridge design can lead to innovative solutions for both new constructions and the retrofitting of existing bridges. This approach aligns with modern engineering trends aiming for adaptable and sustainable infrastructure.

A.2.3 Educational Value:

A. STEM Learning:

This project provided hands-on experience with STEM concepts, particularly in engineering and physics. It encouraged critical thinking, problem-solving, and collaboration among participants.

B. Public Awareness:

Demonstrating the hydraulic bridge model can help raise public awareness about the importance of modern engineering solutions in infrastructure development. It can inspire students and the community to appreciate and pursue careers in STEM fields.

A.2.4 Challenges and Improvements:

A. Challenges Faced:

Some challenges included ensuring airtight connections in the hydraulic system to prevent leaks and maintaining the stability of the bridge during operation.

B. Possible Improvements:

Future improvements could include using stronger materials for increased load capacity, integrating more precise control mechanisms for smoother operation, and experimenting with different fluid types to enhance performance.

CONCLUSION

Our project, "Fluid Mechanics in Action: The Future of Thai Bridges with Hydraulic Technology," successfully demonstrated the principles and potential of hydraulic technology in bridge construction. The results showed that a simple hydraulic system using syringes and popsicle sticks could effectively lift and support a bridge deck, highlighting the practical applications of fluid mechanics. This project not only underscores the relevance of hydraulic bridges in enhancing Thailand's infrastructure but also serves as an educational tool to inspire future innovations in engineering.

The integration of hydraulic technology into bridge design represents a significant advancement in addressing the challenges posed by environmental factors such as flooding. By exploring these innovative solutions, this project aims to contribute to the development of more resilient and adaptable infrastructure, ultimately enhancing the safety and reliability of bridges in Thailand.

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SCIENCE PROJECT DOCUMENTATION