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Research Paper

VERTEX : The Vertical Rotary Bridge-1

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ABSTRACT Transportation and connectivity between locations separated by considerable differences in elevation remain significant challenges in hilly, mountainous, and geographically constrained regions. Conventional solutions such as roads, bridges, tunnels, and switchback routes often require substantial land alteration, high material usage, and continuous maintenance, prompting exploration of alternative approaches that may provide more direct and controlled connection between different elevation levels. In response to this need, the present study proposes VERTEX, a conceptual vertical rotary bridge system designed as an innovative rotary transportation concept. The VERTEX concept envisions a large rotating wheel structure supported by a central axle with passenger cabins mounted at defined positions along the rotating frame. Unlike conventional bridges that provide a fixed horizontal link, VERTEX employs controlled rotational motion to transport passengers between different levels. The proposed system integrates principles of structural engineering, mechanical rotation, cabin stabilization, and transportation infrastructure planning. The rotating mechanism is envisioned as a balanced frame rotating about a central shaft or axle. Cabin stabilization is central to passenger safety and comfort. Because cabins attached to a rotating wheel naturally change orientation as the structure turns, a stabilization mechanism would be required to maintain an upright or near-upright position. Possible approaches may include pivoting cabin mounts, counterweight systems, or guided suspension mechanisms. Structural analysis would play a major role in assessing stresses, deflections, buckling risks, and behaviour under combined loads. Finite element modelling could be used to simulate static and dynamic load cases. Environmental factors such as wind loads, weather exposure, and material degradation would necessitate careful design detailing and maintenance planning. Safety is a fundamental requirement, including emergency braking, controlled acceleration and deceleration, mechanical locking mechanisms, position sensing, and structural health monitoring. Station design would require accurate alignment for boarding and disembarking, coordinated control of cabin movement and speed reduction. The foundation and support structures would need to accommodate site-specific ground conditions, potentially requiring deep foundations or reinforced configurations adapted to hilly terrains. The proposed research methodology includes conceptual development, mechanical calculations, structural modelling, finite element simulations, and scaled

prototype testing. A scaled prototype would allow observation of cabin orientation, mechanical stability, and basic control principles, providing preliminary evidence for or against feasibility. While the concept is not presented as an immediate practical construction project, it aims to establish a technical foundation for further research into rotary transportation systems. Keywords: vertical rotary bridge, rotary transportation system, rotating wheel structure, vertical transportation, cabin stabilization, structural analysis, finite elements, alignment, drive mechanism, dynamic behaviour, safety system, hilly terrain transport, prototype development.

1. Introduction

Bridges are essential elements of modern transportation infrastructure. They provide continuous movement of vehicles, pedestrians, and rail traffic across rivers, canals, harbours, railway corridors, and other physical barriers. However, a conventional fixed bridge crossing a navigable waterway can interfere with vessel movement unless sufficient vertical clearance is provided.

Movable bridges provide an alternative solution. Their primary purpose is to temporarily move a portion of the bridge out of the navigation path when vessels need to pass. Major categories include bascule bridges, swing bridges, and vertical-lift bridges. Modern movable-bridge design standards specifically address structural, mechanical, hydraulic, electrical, seismic, vessel-collision, and operational considerations. The current AASHTO LRFD Movable Highway Bridge Design Specifications include requirements for these major bridge types. AASHTO Journal+1

Vertical-lift bridges are particularly attractive where relatively long movable spans are required. In a conventional vertical-lift system, the movable span rises vertically while remaining substantially parallel to its original position. Counterweights are commonly used to balance the span, thereby reducing the mechanical energy required for operation.

The VERTEX concept extends this general idea by introducing a rotational component into the vertical movement of the bridge. The objective is to create a compact and controlled movement in which the bridge can transition between a normal traffic position and a clearance position using coordinated vertical and rotary motion.

The concept is particularly relevant to congested urban waterways, industrial ports, canals, and locations where the available space around the bridge is limited.

2. Background and Literature Review

2.1 Development of Movable Bridges

Movable bridges have existed for centuries, initially using relatively simple manually operated mechanisms. The development of canals and navigation routes created a need for bridges that could temporarily clear the navigation channel.

Historical research by Griggs documents the development of metal vertical-lift bridges from the nineteenth century, including important contributions by engineers such as Squire Whipple and J. A. L. Waddell. The development ultimately led to sophisticated vertical-lift structures capable of accommodating both roadway/rail traffic and navigation.

One significant example is the South Halsted Street Lift Bridge designed by J. A. L. Waddell. The bridge was selected partly because a conventional rotating draw span would create undesirable obstruction to navigation. Structure Magazine

2.2 Vertical-Lift Bridges

A vertical-lift bridge normally consists of:

- Movable bridge span
- Supporting towers
- Counterweights

- Wire ropes or chains
- Sheaves
- Drive machinery
- Guide systems
- Electrical/control equipment
- Locking mechanisms

During operation, the movable span travels vertically between its closed and open positions.
Modern systems may use tower-mounted machinery or machinery associated with the movable span. Research on movable bridge machinery distinguishes tower-drive and span-drive configurations and describes the use of sheaves, ropes, traction mechanisms, and counterweights.

2.3 Need for an Alternative Concept

Although vertical-lift bridges have significant advantages, they can require tall towers and considerable overhead space. A conventional swing bridge, on the other hand, requires sufficient horizontal space for the rotating span.
VERTEX seeks to investigate whether a combination of vertical translation and controlled rotation can provide a more compact operating envelope.

3. Problem Statement

Conventional fixed bridges may restrict navigation, while existing movable bridges can require substantial horizontal or vertical operating envelopes.
The principal engineering problem addressed by this research is:
Can a bridge span be designed to use controlled vertical and rotary movement to provide navigational clearance while maintaining structural stability, operational safety, and reasonable energy requirements?
The research therefore investigates a conceptual bridge system called VERTEX — Vertical Rotary Bridge.

4. Objectives

The major objectives of the proposed VERTEX system are:

1. To develop a conceptual movable bridge based on combined vertical and rotary motion.
2. To provide adequate clearance for waterway traffic.
3. To minimize the horizontal operating space required by conventional swing bridges.
4. To investigate a mechanically balanced operating system.
5. To develop a safe and controllable movement mechanism.
6. To investigate the structural behaviour of the bridge under static and dynamic loads.
7. To evaluate the feasibility of electrical, hydraulic, or electromechanical actuation.
8. To investigate the potential integration of sensors and automated control.
9. To compare the proposed concept with conventional movable bridges.
10. To establish a foundation for future physical modelling and numerical simulation.

5. Proposed VERTEX Concept

5.1 General Concept

VERTEX is proposed as a hybrid movable bridge combining:

- Vertical translation
- Controlled rotation
- Counterbalancing
- Mechanical/electromechanical actuation
- Automated position control

In the closed position, the bridge functions as a conventional roadway or pedestrian crossing. When a vessel approaches, the system temporarily removes the bridge deck from the navigation envelope. The deck is first released from its structural locks and then raised through a guided mechanism. Depending on the final configuration, a controlled rotary movement can orient the deck into a compact elevated position.
The essential concept can therefore be represented as:
Closed position → Unlock → Vertical movement → Rotary movement → Open position
and during restoration:
Open position → Rotary return → Vertical lowering → Alignment → Locking

Conclusion

- VERTEX — the Vertical Rotary Bridge — is proposed as an innovative movable-bridge concept combining vertical translation with controlled rotary motion. The concept is inspired by established movable-bridge technologies, particularly vertical-lift bridges, while introducing an additional degree of movement intended to provide a compact operating configuration.
- Existing engineering research confirms the feasibility and historical maturity of vertical-lift bridge technology. Modern design standards address the structural, mechanical, electrical, hydraulic, seismic, vessel-collision, and operational aspects necessary for safe movable bridges.
- The main potential advantage of VERTEX is its ability to combine the clearance characteristics of vertical movement with the spatial flexibility of rotary movement. This could make the concept attractive for constrained urban waterways, canals, ports, and specialized transportation infrastructure.
- However, the introduction of rotational movement also creates additional structural and mechanical challenges. In particular, synchronization, torsional behaviour, bearing loads, dynamic effects, fatigue, wind loading, emergency operation, and control-system reliability require detailed investigation.

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