

Investigation of Structural Behavior and Computational Modeling of a Transformable Guiding Bridge

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Abstract This paper investigates the structural behavior and computational modeling of a transformable guiding bridge system intended for rapid deployment in extreme operational conditions. The performance of temporary guiding bridges is governed not only by their structural configuration but also by the accurate evaluation of internal forces and deformations arising during both installation and service stages, which is particularly critical for emergency, rescue, and military engineering applications.

The distinguishing feature of the proposed bridge system lies in its transformable structural behavior. During the installation phase, the bridge functions as a temporary multi-span structure supported by deployable auxiliary supports, whereas during service it is converted into a single-span system. This transformation leads to a significant redistribution of internal forces and necessitates a computational approach capable of capturing both structural states.

A realistic calculation model was developed to represent the actual behavior of the bridge, incorporating modular geometry, temporary transformable supports, and appropriate boundary conditions. Structural analysis was carried out using MIDAS Civil 2024 software, based on the displacement-based finite element method. The model considers permanent, live, and temporary installation-related loads corresponding to unfavorable working conditions.

The results demonstrate that maximum bending moments, shear forces, and deflections occur during the installation stage but remain within allowable normative

limits. The study confirms that the application of transformable temporary supports significantly improves structural safety and constructability. The proposed guiding bridge system provides a reliable and efficient solution for rapidly deployable transport infrastructure in extreme environments.

Keywords: transformable guiding bridge, structural performance, finite element analysis, temporary bridge, extreme conditions

1. Introduction

The reliable operation of rapidly deployable guiding bridges under extreme conditions requires a comprehensive understanding of their structural behavior throughout all stages of deployment and use. In temporary transport infrastructure, particular attention must be paid to load-bearing capacity, stiffness, and serviceability during both installation and operational phases [5].

Transformable guiding bridges exhibit a dual structural behavior. During installation, they operate as temporary multi-span systems supported by auxiliary deployable supports, while in service they are transformed into single-span structures. This transition induces a redistribution of internal forces and represents a critical aspect of their structural assessment [1].

Most existing research on rapidly deployable bridges addresses permanent or semi-permanent systems [1], whereas the combined analysis of transformable structures considering both installation and service stages remains limited in open literature [4]. This gap highlights the

relevance of the present study.

The objective of this paper is to analyze the structural performance and computational model of a transformable guiding bridge system and to assess its suitability for application in extreme operational conditions [2,5].

2. Computational Scheme and Structural Model

To evaluate the structural response of the transformable guiding bridge, a computational model was developed representing both the installation and operational stages. The model accounts for modular geometry, temporary transformable supports, and realistic boundary conditions reflecting actual deployment scenarios [1,5].

The bridge is modeled as a modular steel

girder system. During installation, deployable temporary supports create a multi-span structural scheme. Upon completion of assembly, these supports are folded, and the bridge operates as a single-span system. This modeling strategy allows identification of the most unfavorable structural conditions [4].

Temporary supports are represented as adjustable vertical elements providing intermediate reactions during installation. Primary structural members are modeled using beam-type finite elements, enabling calculation of bending moments, shear forces, and deflections. Support conditions are defined in accordance with common temporary bridge design practice and applicable standards [2,3].

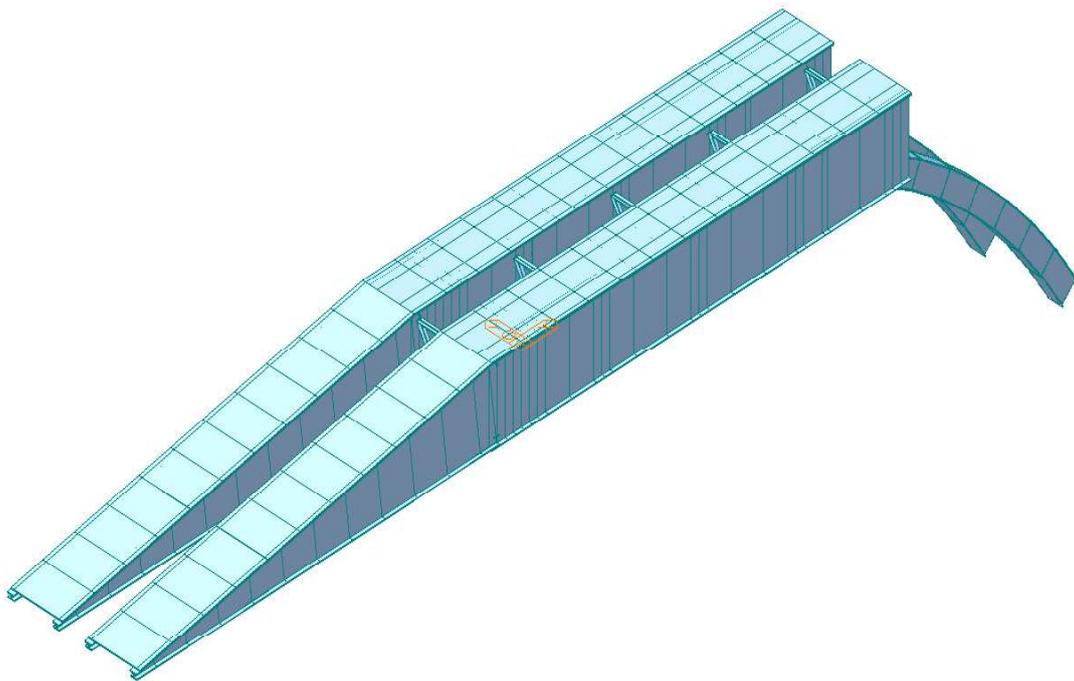


Figure 1 — Structural computational scheme of the transformable guiding bridge

Structural analysis was performed using MIDAS Civil 2024 software, employing the displacement-based finite element method, which is widely used for bridge analysis due to its reliability in evaluating internal forces and deformations.

3. Loads and Computational Parameters

The computational analysis considers load combinations relevant to rapidly deployable

bridges operating under emergency and extreme conditions. Permanent loads include the self-weight of the structural elements, calculated based on geometric properties and material

densities and applied as distributed loads along the span [1].

Live loads are represented by the NG-60 vehicular load model, which corresponds to unfavorable loading scenarios typically adopted for temporary military and emergency bridges [5]. The load model is applied to generate critical internal force effects in accordance with

engineering practice [1,5].

Temporary loads associated with staged installation are also included, accounting for the sequential placement of bridge sections and activation of temporary supports. Where appropriate, dynamic amplification effects are considered to reflect moving-load influence on the structural response [1,2].

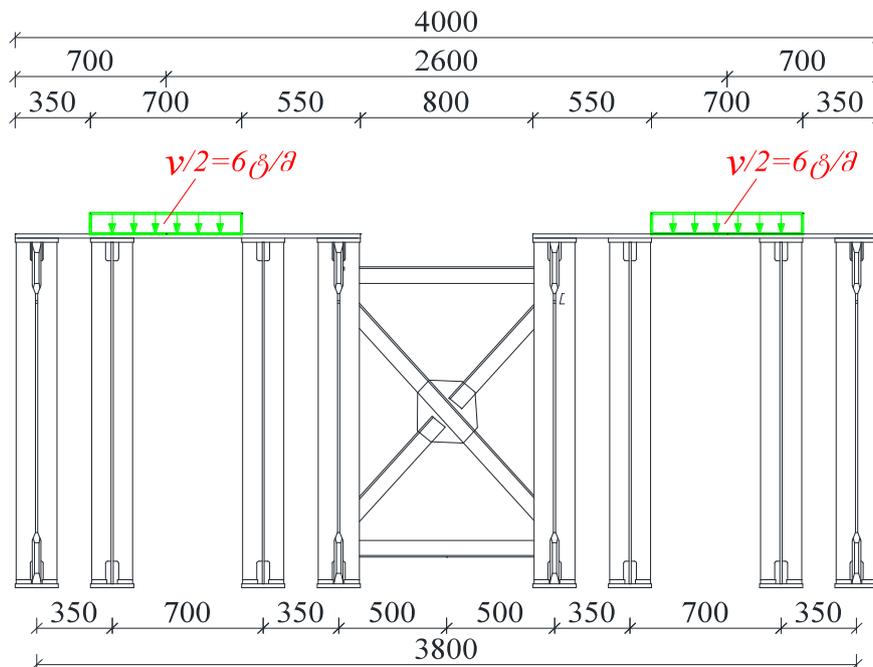
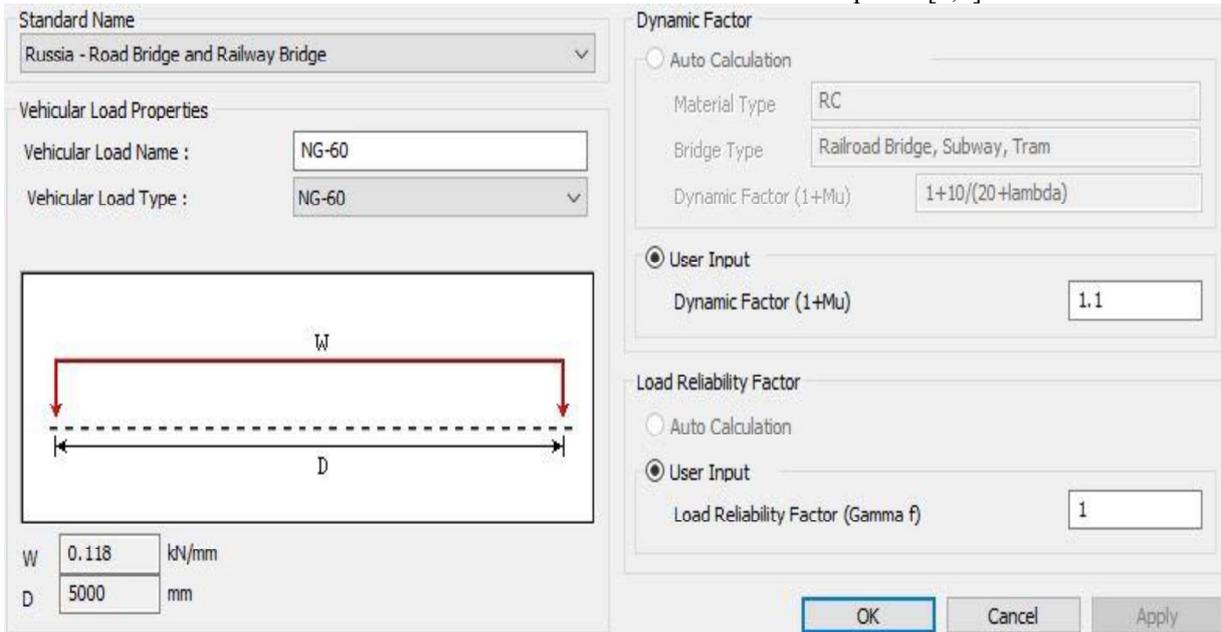


Figure 2 — Application of the NG-60 live load model on the bridge span

4. Results and Discussion

The presented results correspond to the most unfavorable computational stage, which occurs during installation when temporary supports are engaged. Analysis of bending moments indicates that the maximum

bending moment (M_y) develops near the mid-span region. The obtained values remain within allowable limits, confirming adequate structural strength under critical conditions [2,3].

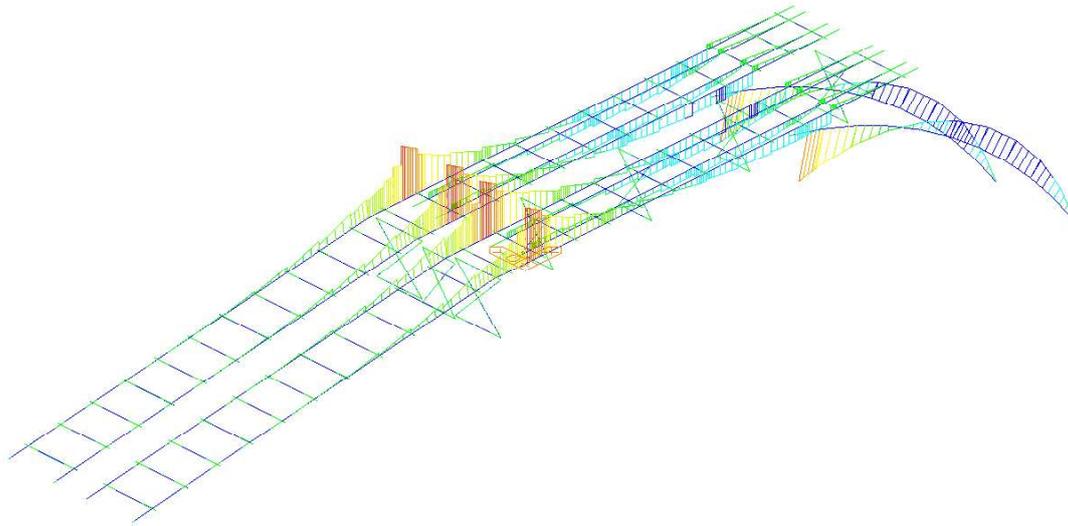


Figure 3 — Bending moment (M_y) distribution for the critical installation stage

Shear force analysis shows peak values in regions adjacent to support locations, which is consistent with the expected behavior of girder-type bridge systems. The calculated

shear forces do not exceed the design capacity of the structural members under the adopted load combinations [1,2].

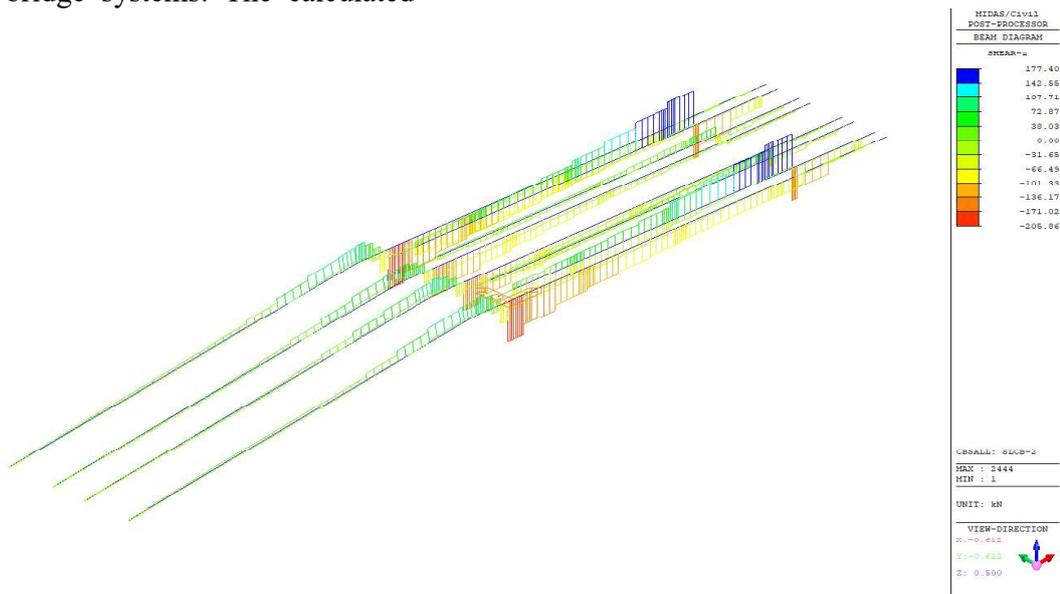


Figure 4 — Shear force (Q_z) distribution for the critical installation stage

Deflection analysis demonstrates that maximum vertical displacement (D_z) occurs at mid-span and remains below the

serviceability limits specified by relevant design standards for steel bridge structures [2,3].

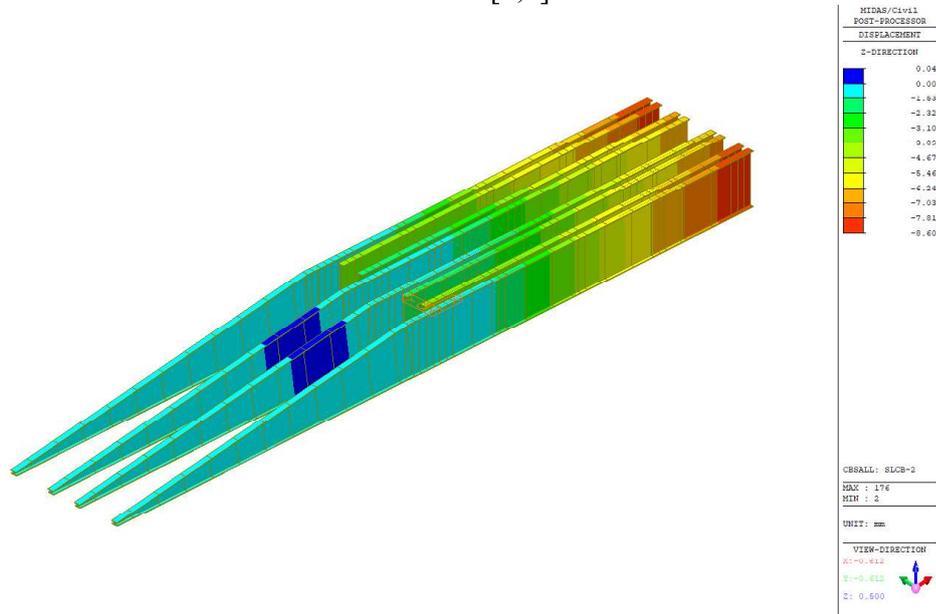


Figure 5 — Vertical deflection (D_z) diagram for the critical installation stage

Overall, the results confirm that the use of transformable temporary supports significantly reduces peak internal forces during installation, enhancing structural safety and constructability. The transition to a single-span operational configuration does not introduce unfavorable structural effects [4,5].

5. Conclusions

This study presented a structural performance analysis and computational model of a transformable guiding bridge system designed for rapid deployment under extreme conditions. The proposed modeling approach effectively captures the bridge behavior during both installation and operational stages, reflecting its transformable nature [4].

The results indicate that the most critical structural conditions occur during installation, while bending moments, shear forces, and deflections remain within allowable limits prescribed by relevant standards and established temporary bridge practice [2,5]. The application of transformable temporary supports improves stability during assembly and supports safe and efficient deployment.

The proposed guiding bridge system represents a practical and adaptable engineering solution for temporary transport infrastructure, offering reduced installation time and enhanced operational reliability. The adopted

computational methodology provides a foundation for further optimization and future development of transformable bridge systems [1,4].

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