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Cross-Section Optimization of a Rapidly Deployable Causeway System

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1. Abstract

Rapidly deployable causeways can provide critical access from ship to shore for military and disaster relief. Existing causeways can provide access to damaged and small ports, but have the major limitation of only being transportable and emplaceable by large strategic sealift vessels. Furthermore, existing systems are heavy, have high packaged volumes, are assembly-intensive, and cannot be delivered by air. In response to the need for new system that is lightweight, modular, quickly emplaced, and does not require deep-draft vessels with high-load capacity cranes to transport and unload them, the Engineer Research and Development Center has developed a prototype comprised of aluminum modules connected by compliant connections and supported by pneumatic floats. Though this system shows great promise and has performed well in recent field experiments/assessments, areas for further improvement include eliminating the compliant connections with their inherent complexity and weight. These connections were designed for sufficient rigidity to meet deflection limits while providing rotational flexibility to take advantage of float buoyancy. The authors have re-conceptualized this existing prototype such that the module itself provides the required flexibility under given design loads, thereby eliminating the compliant connections. More specifically, the superstructure was designed to meet a target moment of inertia to permit a given curvature under a design moment.

This re-conceptualization is a challenging design problem since self-weight and packaged volume are at a premium, and both should be minimized. Structural optimization can be a valuable tool to address these competing priorities. This paper presents the results of optimization studies leading toward this re-conceptualization. A box girder cross-section was pre-determined and design variables included the thickness of the flanges and webs and the width of the bottom flange. Glass fiber reinforced polymer is proposed to replace aluminum as the material for the superstructure. Constraints included a minimum target value for the moment of inertia, restrictions on the structural behavior, and additional geometric specifications. A number of studies were performed to investigate competing priorities related to the self-weight, packaged volume, and a desired target value for the moment of inertia. These studies include single-objective optimization for: (1) minimum weight, (2) minimum moment of inertia, (3) minimum weight with the bottom flange width constrained, (4) minimum moment of inertia with the bottom flange width constrained, (5) minimum weight with the bottom flange width constrained and the depth of the cross-section as an additional design variable, and (6) minimum moment of inertia with the bottom flange width constrained and a variable depth. Simulated Annealing was employed since it is intuitive, fast, and capable of handling the nonlinear objective functions, nonlinear constraints, and discrete conditions of the design problem.

The results of these studies informed a multi-objective structural optimization process which was utilized to design a cross-section for minimum self-weight and for a target system flexibility. This research offers the potential to develop a novel floating causeway that no longer achieves its rotational compliance through heavy and complex connections. This system balances the priorities of the proposed re-conceptualization with self-weight and packaged volume.

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