Material Cost Minimization Problem for Aluminum Alloy Beam using Beam String Structure

Shota Mizuno[1], Yuki Chikahiro[2*], Shigeru Koyama[3]

[1] Graduate School of Science and Technology, Shinshu University, 380-8553, 20w3013e@shinshu-u.ac.jp
[2*] Shinshu University, 380-8553, chikahiro@shinshu-u.ac.jp
[3] Shinshu University, 380-8553, koyama@shinshu-u.ac.jp

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Industrial-use aluminum alloy materials are excellent in the lightweight and corrosion resistant, but inferior to the stiffness and material cost than steels. When the aluminum alloy is used to a girder bridge, the member cross-section must be larger than that of the steel because the same deflection limit must be applied regardless of the material types, and it results in higher material costs. Therefore, the aluminum alloy materials are often used not in the bridge girders but in the bridge components such as guardrails and lighting posts [1]. In this study, we try to apply the aluminum alloy materials to Beam String Structure (BSS) in order to improve the stiffness and reduce the material cost. In the BSS, the girder is supported by the cables through the struts to generate the negative bending moments, which can increase the stiffness of the entire girder [2]. In this paper, superiority of the BSS made of the aluminum alloy material is clarified through a combination of topology optimization and material cost minimization problem.

Fistly, configurations of the BBSs were determined by the topology optimization using grandstructure method. Then, six types of the BSSs were adopted in the material cost minimization problem, with three cable diameters and the number of struts of 1 and 2. For comparison to the BSSs, a simple supoprted steel and aluminum alloy beam were also considered. The material cost is adopted by the relative cost per unit mass multiplied by the mass of materials, referring to the literature [3]. The cross-section of the beam and strut and the height of the strut were used as design variables. The height of the beam, the width and height of the strut, the distance between the struts, the yield and buckling stress, and the deflection limit were used as constraint conditions.

The material cost of the simple supported aluminum alloy beams was approximately 42% higher than that of the simple supported steel beams. On the other hand, the material cost of the BSSs made of the aluminum alloy material was equal to or lower than that of the simple supported steel beams. Regardless of the number of struts, the material cost decreased as the cable diameter increased. Furthermore, the relationship between the span length and material cost was investigated. In contrast to the simple supported steel beam, which no longer satisfies the constraint when the span reaches a certain length, the BSS made of aluminum alloy material satisfies the constraint even when the span increased by 80% compared with that of simple supported steel beam. These results suggest that the development of lighter weight and longer span structures using aluminum alloy materials can be expected.

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