NUMERICAL STUDY ON REINFORCEMENT AND OPTIMIZATION OF A SCISSORS STRUCTURE

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1. Introduction

The world faces many types of natural disasters, such as earthquakes, floods or tsunamis. In case of damage of a bridge caused by these forces of nature, quick recovery using a rapid system of construction would be very helpful for the residents in the disaster - stricken area. To solve these problems, the authors have proposed a scissor type of deployable bridge - Mobile Bridge$^{\mathrm{TM}}$ (MB) - based on the concept of the Multi-Folding Micro-structures[1], [2]. Such type of a structure is different from typical truss structures because of the dominant effects of bending moments. However, the design of the MB enables to reduce the construction time on site by deploying the structural frame directly over a damaged bridge or road.

Our previous research focused on the fundamental mechanical properties for the MB. Several analytical methods were proposed based on the beam theory and equilibrium equations method[3]. We have achieved to develop experimentally a real-scale MB experimentally as shown in **Fig. 1**. On the other hand, to provide high level of safety emergency bridge in the disaster area, an effective reinforcing method and optimal bridge design are required. This paper evaluates the reinforcement method by introduction of additional strut members. The sectional areas of the scissor and strut members can be further optimized for improving the performance of the MB.

2. Optimization methodology

This paper deals with the limit load capacity problem, which is defined with constraints imposed on weight W, stress σ, and displacement δ in **Eq. (1)**.

(1)
$$\begin{aligned} &\text{Maximize} \quad P \quad , \\ &s.t. \quad W < W_{initial},\ \sigma_{c,\,s,\,o} < \sigma_y,\ \delta < \delta_y \end{aligned}$$

where symbols $\{c, s, o\}$ are each boundary condition of the MB in cantilever, simple supported, and operational state. Thus, three different boundary conditions have to be considered in the case of

Figure 1. A two-unit experimental Mobile Bridge.

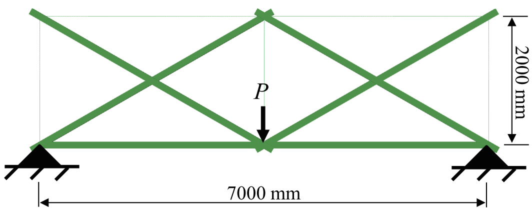
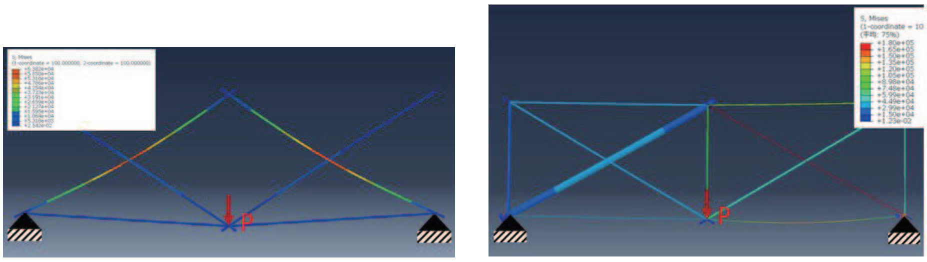


Figure 2. Initial numerical model.



(a) (b)

Figure 3. Stress distribution of the MB under limit load P. (a) Initial model (P = 2.1 kN). (b) Optimized model (P = 50.4 kN).

scissors-type bridge. We can solve this optimization problem by changing each sectional area of a scissor and strut components satisfying the constraint conditions based on the previous authors' paper[4].

3. Numerical example and results

Initial numerical model is built up by ABAQUS 6.12 as shown in **Fig. 2**. At full extension, the total length of the span is 7.0 m and the height is 2.0 m. The sectional and material properties of the main frame and strut components are assumed to A = 28.0 cm^2, I = 1146.3 cm^4, E = 62.5 GPa, and ρ = 2.7 g/cm^3. The constraint conditions of σ and δ are assumed to 180 MPa and 14 mm, respectively. The weight W is defined same frame weight in the initial model.

Both numerical results in the initial and optimal state are shown in **Fig. 3**. The limit load capacity of the MB1.0 was increased more than 10 times that in the initial after reinforcement and optimization procedure. It is considered that high bending stress within the initial model is reduced by additional strut members.

The change of basic dynamic properties was evaluated for the MB1.0 after optimization. The first natural frequency f of the model is 12.8 Hz, with dominant deformation mode in the vertical direction. From the point of view of the excitation by human and vehicle traffic in impact, the possibility of resonance phenomenon is negligible. These results allow to say that the proper reinforcement and structural optimization makes the MB a safe structure.

4. References

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