NUMERICAL STUDY ON REINFORCEMENT AND OPTIMZIATION OF A SCISSORS STRUCTURE

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1. Introduction

There are many types of natural disasters, such as earthquakes, floods, and tsunamis in the world. If a bridge was broken by these disasters, quick recovery using a rapid constractable system would be hoped for the residents in the disaster - stricken area. To solve these social 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.

The previous our research focused on clarification of the fundamental mechanical properties for the MB. Several analytical methods were proposed based on the beam theory and equilibrium equations method[3], and we have achieved to develop 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. In this paper, the utility of the reinforcement by strut members and its optimization are evaluated. The sectional areas of the scissor and strut members can be optimized for improving the bridge's performance.

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)**.

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

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.

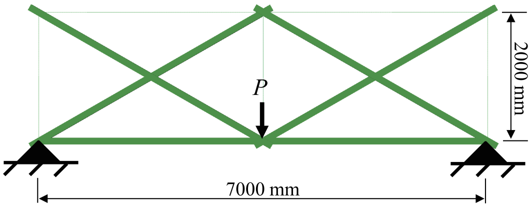
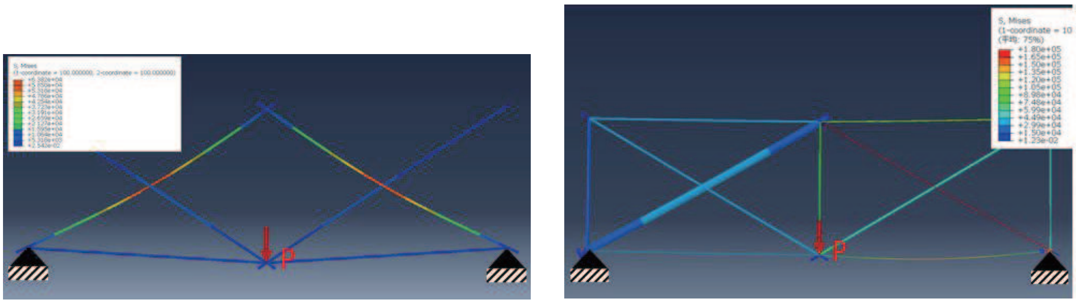


Figure 2. Initial numerical model.



(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

3.1. *Numerical model*

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.

3.2. *Change of limit loading value*

Both numerical results in the initial and optimal state are shown in **Fig. 2**. Although the initial model is easily to deform even with a small loading value, the limit load capacity of the MB1.0 was increased to more than 10 times that in the initial by reinforcement and optimization procedure. It is considered that high bending stress within the initial model is reduced by additional strut members.

3.3. *Change of dynamic property*

Based on the obtained optimal results, the change of dynamic property was evaluated by eigenvalue analysis. When the natural frequency f was 12.8 Hz, the initial model occurred large deformation in the vertical direction. From the point of the traffic vibration such as human and vehicle impact, there is not so high possibility of resonance phenomenon. The optimal model was also not measured high natural frequency because of increment of its stiffness. These results allow to say that the MB enables to be a safety structure by proper reinforcement and optimization method.

4. References

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