Structural Analysis of Deployable Structure with Scissor-like-element in Architectural Design Class

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Summary

A deployable structure with scissor-like-element is designed and constructed in architectural design class. In parallel, structural analyses are carried out using general finite element analysis program to evaluate the stability of intermediate models considered in the design process and determine the configuration of the final product. Rods in deployable structure with scissor-like-element are modeled by beam element and hinge and pivotal joints are modeled by setting different nodes per rod located at these joints and imposing constraint equations on these nodal degrees-of-freedom. Stiffening effect by nylon ropes set up diagonally between hinge joints after the deployment is evaluated by the eigenvalue analysis. Beside structural analysis, architectural design process and the final product of deployable structure with scissor-like-element are described.

Keywords: Deployable structure; Scissor-like-element; Architectural design; Structural analysis; Finite element analysis

1. Architectural design process

A deployable structure with scissor-like-element (e.g. [1], [2]) was designed in architectural design class. Students firstly determined the usage of the architecture as a temporary tent used for a resting place in some kind of events. Next, they studied the form of structure by making many models. As a result, simple form of vault was adopted. Thin and slender cedar timber was selected as the material of rod considering the reduction of self-weight of the structure and eccentric moment generated at pivotal joint. Span and rise of arch were decided considering wind load, area of floor, and workability. Weight of anchor requited to withstand wind load was calculated by hand. Initially, deployable structure as shown in Figure 1(a) was considered from the esthetic point of view. Through making various vault-form models, it was found that there were strong arch and weak arch. Finally, deployable structure with the strong-weak-strong arch as shown in Figure 1(b) is selected for the final design.

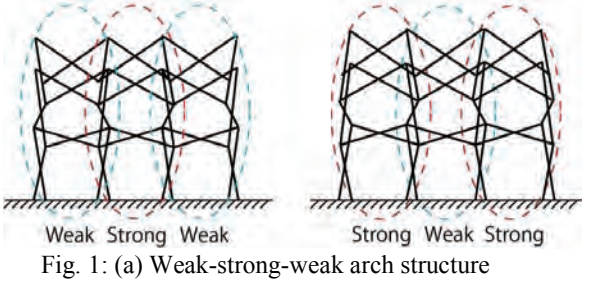


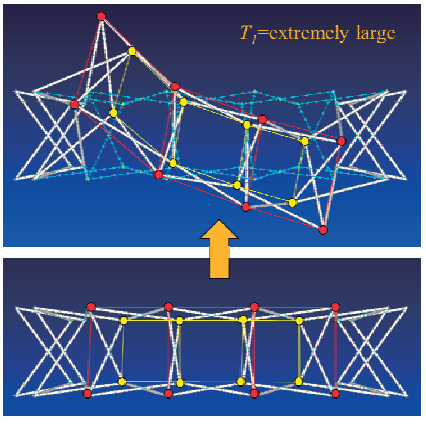
Fig. 1: (a) Weak-strong-weak arch structure
(b) Strong-weak-strong arch structure

2. Structural analysis

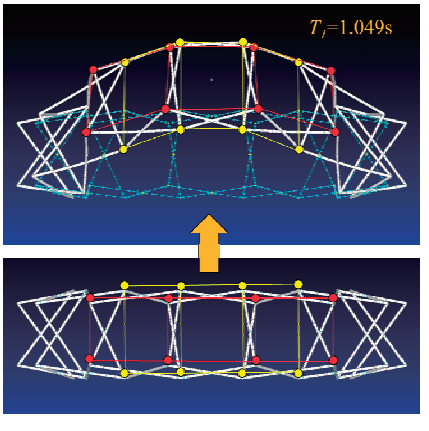
The eigenvalue analyses were carried for the weak, strong, and strong-weak-strong arch structures using general finite element analysis program. The 1st-natural period of the weak arch was extremely large and then this was unstable due to the twisted deformation as shown in Figure 2(a). The 1st-natural period of the strong arch was 1.049s and this is stable as shown in Figure 2(b). These results contributed the selection of vault-form consisting of the strong-weak-strong arch as in Figure 1(b) for the final product. The strong-weak-strong arch structure was stiffened by nylon ropes set up diagonally between hinge joints outside. The gravity analysis results for the model with membrane roof is shown in Figure 3. The maximum vertical displacement is about 4mm.

3. Final product of deployable structure with scissor-like-element

The final product of deployable structure with scissor-like-element designed and constructed by the students is shown in Figure 4.



(a) Weak arch structure



(b) Strong arch structure

Fig. 2: 1st-mode shapes of weak and strong arches (X-Y view)

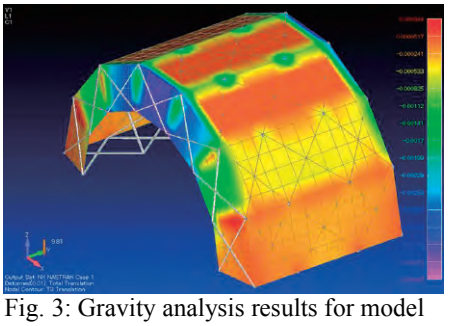


Fig. 3: Gravity analysis results for model

Fig. 4: Final product

References

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