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Using Accordion-Style Structured Tubes to Better Support Bridges

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Abstract

In recent years, bridges built during the high-growth period have been deteriorating, and these aging bridges need to be rebuilt. We would like to suggest a bridge bearing using an accordion style structured tube (ASST), which has higher strength against horizontal forces than conventional ones. In this study, we measured the strength against vertical force and horizontal force, which are basic properties of ASSTs, by varying the number of layers and width of the tubes. The results showed that the strength against vertical forces decreases as the number of layers and width increase, while for the strength against horizontal forces, there is a moderate number of layers that maximizes the strength.

1. Introduction

In recent years, "origami engineering", in which sheets of various materials are folded to provide various functions, has been attracting attention. Practical examples include diamond-cut beverage cans that consume less material than standard cans, and solar panels folded using the Miura-ori folding technique, which can be easily folded and unfolded. Having become interested in origami engineering, we discovered prior research on "accordion-style structured tubes".

An accordion-style structured tube is a square cylinder with stacked trapezoids and flexible sides that have an accordion-like structure. This cylinder is springy in the vertical direction and elastoplastic in the horizontal direction, meaning that it can undergo both elastic and plastic deformation when subjected to external forces. As an idea for utilizing this tube in society, we are considering its use as a bridge bearing.

A bridge bearing is a component placed between the pier and the deck of a bridge and must be strong enough to withstand both horizontal and vertical forces during earthquakes. The accordion-style structured tube is said to have high strength against horizontal forces, and if it is utilized for bearings, the strength of bridges can be greatly increased.

2. What We Hope to Clarify in This Research

In a previous study, changes in strength when the height of the tube was varied were investigated. However, since the bearing is a component that is placed between the pier and the deck of a bridge, it is important to determine the optimal shape of the side trapezoids and the number of accordion layers that maximize the strength of a cylinder of a certain height. This will ensure that the bearing is strong enough to withstand both horizontal and vertical forces in earthquakes.

Therefore, in this study, we will clarify the relationship between the shape of the trapezoids on the sides, the number of accordion layers, and the strength of the cylinders without changing the height of the cylinders throughout the experiments. The results of this study could contribute to the development of stronger and more durable bridges, enhancing the safety of communities and the infrastructure that supports them.

3. Method

Experiment 1-1

We aimed to clarify the change in strength against vertical force when the number of tiers of ASSTs varied from 4, 8, to 16 tiers in the first experiment. Several models of ASSTs with different steps were created using a 3D printer. The material used was ABS resin, the height of the cylinder was 80 mm, and the circumference was 200 mm.

The ASST was placed on a scale, and a jack fixed with a stand was placed on top of it. In this case, the jack was mounted so that it was horizontal. A lever attached to the jack was turned to extend the jack to apply force to the cylinder. At this time, the force applied to the ASST was equal to the value indicated by the scale, and this value was recorded. When the magnitude of the force exceeded a certain value, the cylinder broke and the value on the scale decreased rapidly, so the value just before that point was recorded as the cylinder's strength.

Experiment 1−2

We aimed to reveal the change in the strength against vertical force when the width of the ASSTs varied from 5 mm, 10 mm, and 20 mm in the second experiment. The method is the same as that of the first experiment.

Experiment 2−1

We aimed to reveal the change in strength against horizontal force when the number of tiers of ASSTs varied from 4, 8, and 16 tiers in the third experiment. A model equivalent to that of Experiment 1 was created. A fixture to hold the model in place was also created using a 3D printer. The height of the fixture was 40 mm, half the height of the cylinder.

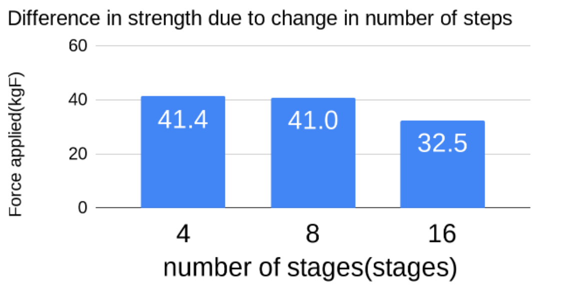
A platform of appropriate height was placed on top of the scale. A jack was placed next to the scale and extended so that it was higher than the box of the scale.

The lower half of the model was placed on the jack, covered with the fixture, and then weighted and secured. The jack was slowly retracted and a shear force was applied by pinching the cylinder between the fixture and the platform. When the magnitude of the force exceeded a certain value, the cylinder broke and the value on the scale decreased rapidly, so the value just before that point was recorded as the cylinder's strength.

4. Result

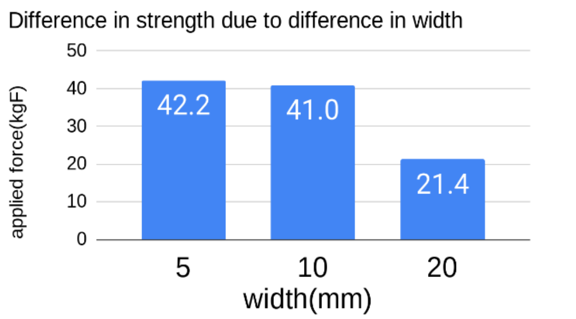
Experiment 1-1

The strength of each step is shown below. The larger the number of steps, the lower the strength.



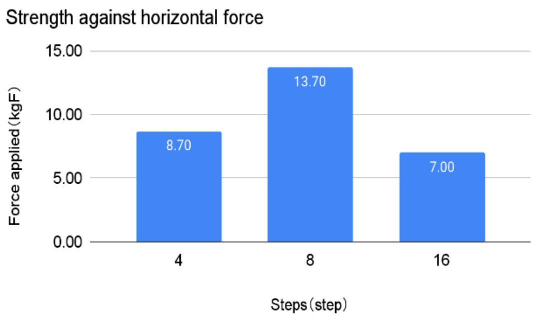
Experiment 1-2

The strength by width is as shown below. The larger the width, the lower the strength.



Experiment 2-1

The strength of each tiers is shown below. From this experiment,the 8-step cylinder was stronger than the 4-step, but the 16-step cylinder was the weakest."



5. Discussion

The result that the strength increases as the number of steps decreases and the width decreases indicates that the strength in the vertical direction increases when the shape is similar to that of a rectangular prism.

The reason why the strength increases as the number of steps decreases is thought to be due to the angle of the trapezoidal shape of the sides. The smaller the number of steps, the larger the angle between the trapezoids on the sides,and the smaller the component of the vertical force that acts to narrow the corner,the less likely the joint is to crack. The same relationship between width and strength can be considered. The smaller the width, the greater the angle between trapezoids, and the less likely the joint is to crack.

6. Future Outlook

We consider using a device for future experiments that can measure horizontal strength more accurately. We want to devise a method to accurately model ASST, including those with large overhangs.

7. References

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