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# *Data Analysis of Planar Deployable Structure with Cross-link Element*

**Jingdu Zhong**

*Chengdu Experimental Foreign Languages School, Chengdu, China*
*977768529@qq.con*

***Abstract.*** This essay focuses on the data analysis of planar deployable structures with cross-link elements, which are widely used in engineering due to their ability to fold and expand. These structures, often employed in architecture and aerospace, use scissor-like mechanisms to control their open area. The paper explores the relationship between angle changes, length, and height in these structures, specifically examining how adjustments in element angles affect the structure's dimensions. A detailed study of a model using 135-degree elements is presented, along with an analysis of non-standard variations where side lengths are reduced, leading to 3D deformations. The essay concludes that as the deployment angle increases, the rate of change in both length and height decreases, and a positive correlation exists between angle changes and gap lengths in non-standard configurations. Future research is suggested in finding correlation equations between angle changes and structural height, as well as integrating motors and autonomous control systems for practical applications in engineering.

***Keywords:*** Planar Deployable Structure, Cross-Link Element, Elliptical Structure

## 1. Introduction

planar deployable structure with cross-link element is the most popular structure and widely use in engineer. This structure is using the Scissor structures to create a foldable deployable object which could open and closed to control the size of its open area to reach different aims [1]. According to this, it is generally use in architecture with the roof of sports center to control light intensity inside or in astronomy use as a door [2].

With people's exploration of space, structures can be unfolded. Gradually becoming well-known to people and used in the operation of spacecraft

Many literatures now mention the design of this structure and its derivative effects. Therefore, it is necessary to conduct certain data analysis on some unfolding structures for future application.

In this paper I focus on some data of the cross-link element for planar deployable structure, such as the changes between it angle and the length of it and the height of it, with some different situation and have shorter in some part and focus on their angle changes.

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## 2. Previous works

With the development of new materials, the concept of expandable structures has been expanded. From the initial stage of folding and unfolding of rods and plates, to the current development of various methods such as inflation hardening unfolding and material deformation unfolding [3].

The application fields of expandable structures are gradually expanding, from the initial aerospace field to multiple fields such as building structures, military engineering, and automotive engineering. In construction engineering, the concept of expandable structures is applied to openable roofs. Compared to traditional roofs, it can rely less on artificial light sources for illumination.

The trend of modern construction engineering technology towards refinement, integration, digitization, and informatization has promoted the application and development of deployable structures in the field of architecture [4,5].

Cross-link element is an element is built by two bar connected bend with some angle, then put two of them into one element and connect flexible at the bended point

In the figure 1, it uses two identical bars to construct a 135degree angle which is an element. Then put two element identical element together and connect them, so there is a cross-link element. (figure 2)

In addition, there is some data about the angle in the design of elliptical circle and the angle of element, which the angle between two element is complementary with angle formed by line connected in their end. With angle 'a' and the angle in the figure 1, that they are added to 180 degrees [1].

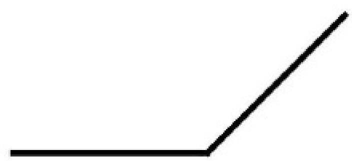

Figure 1. Two identical bars to construct a 135degree angle

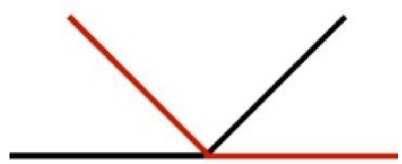

Figure 2. Cross-link element

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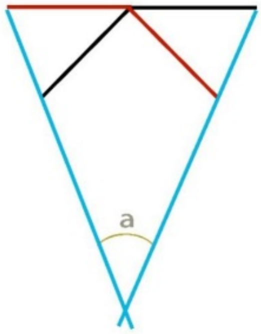


Figure 3. Angleαin element

## 3. The simple model of planar deployable elliptical circle

This model is constructed from two 7cm bars as a 135-degree isosceles triangle, and two such triangles are connected together to form a model with an angle of 45-degree element. Then connect 8 elements together and construct this model.

This model is developed by a circle plan deplorable structure with 135 degrees element, and there are actually 16 of them.

As shown in the figure, this elliptical planar deployable structure has a height and a length. At this moment, we are using the top of this structure. Use one screw to the bottom as its height and usage. The length from the leftmost screw to the rightmost screw represents the relationship between its length, height, and angle change.

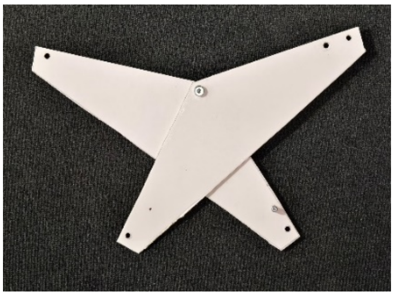

Figure 4. Two 7cm bars as a 135-degree isosceles triangle

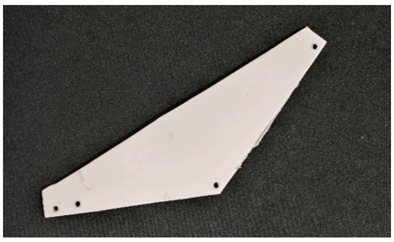

Figure 5. Single 7cm bar as a 135-degree isosceles triangle

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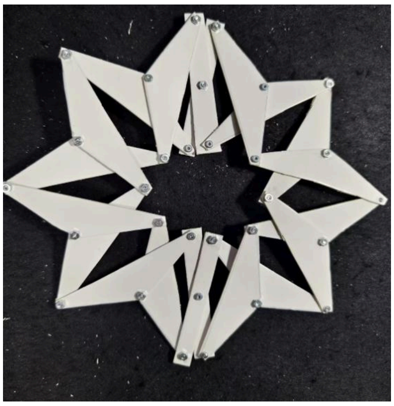

Figure 6. Whole closed structure

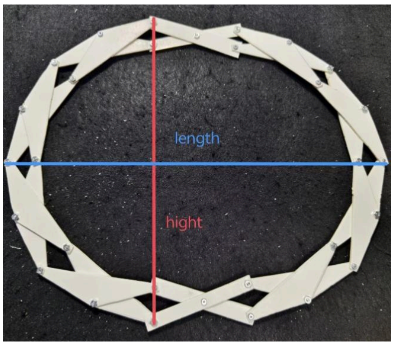


Figure 7. Whole expanded structure

Flat deployable structures require extremely high precision when studied, and often suffer from 3D changes due to element accuracy issues. In response to this problem, the length of bars in three dimensions is worth exploring. Second model explore the impact of reducing its side length on the entire model.

It can be seen that this model will become a 3D model after reducing the length of one side. After unfolding it, it can be found that this model has a gap compared to the original model. And the length of this gap may be an important factor affecting the 3D variation of this model.

At this point, the length of one side changed, causing it to not be fully connected together like a regular expandable closed structure when it was finally connected.

This component is a configuration obtained by subtracting 1cm from one edge of the previous component. At this time, the angle a of the model has not been changed, but the edge length of one side has changed. Therefore, when changing the angle, its length and trend of change will be completely different.

At the same time, it was observed that there was a gap between the two endpoints that were supposed to intersect, and after connecting them into a straight line, the length of this gap varied with the angle1.

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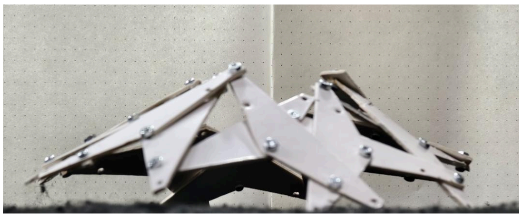

Figure 8. Structure with 1cm decreased

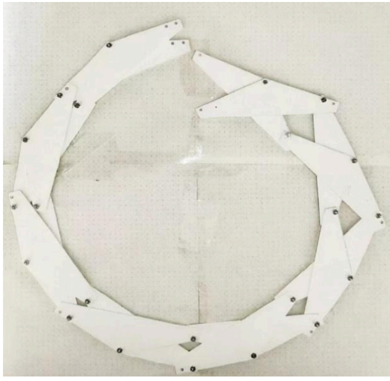

Figure 9. Expanded structure with 1cm decreased

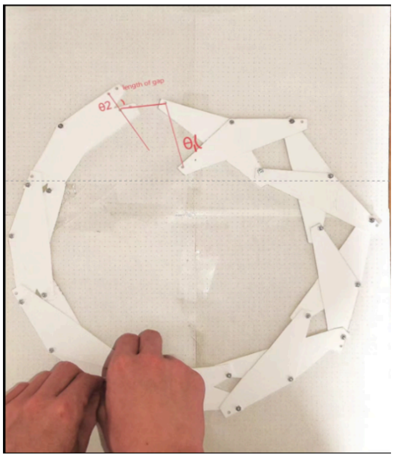


Figure 10. θ1 and θ2 in the structure

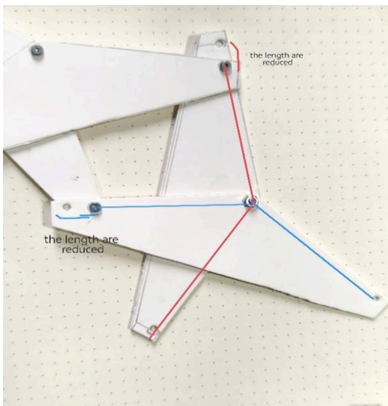


Figure 11. Shorted edge in element

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## 4. Kinetic analysis and phototypes

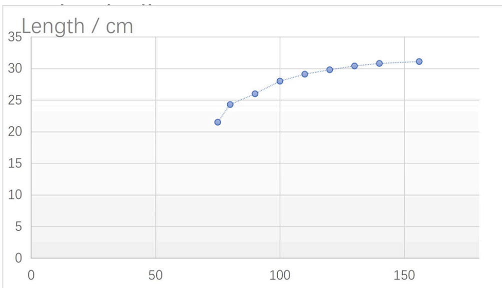


Figure 12. Relationship between length and angle change

As the angle increases, the rate of change in length gradually decreases, that is, the slope of its tangent line gradually decreases.

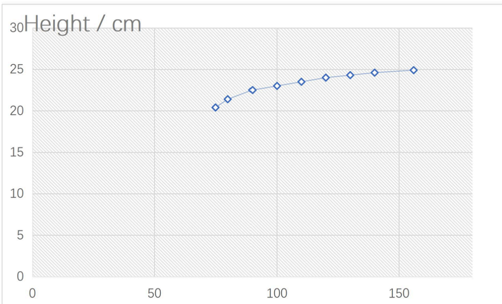


Figure 13. Relationship between height and angle change

Then, the data reflected by this law is the speed at which the angle changes with the amount of length change. And present same situation with the light.

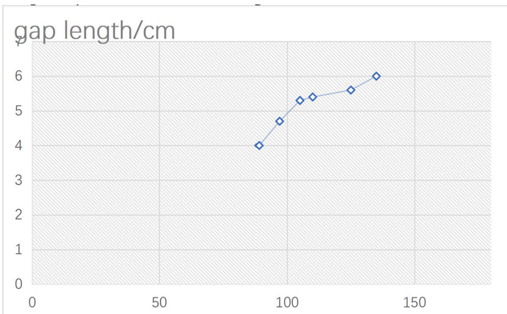


Figure 14. Relationship between gap length and angle1 change

For the not standard one, with one side shorted, there is a gap inside of it, so there is some figure about the gap length and the two angle changes. For the change in angle and gap length, we found that as the angle becomes larger, the length of the gap also gradually increases. This also indicates that they may be positive correlation.

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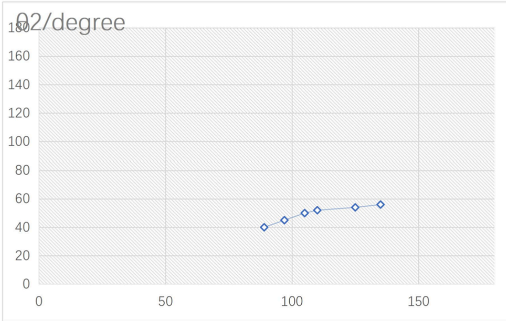


Figure 15. Relationship between gap length and angle2 change

For the changes in θ1 and θ2, as θ1 increases, θ2 also experiences a certain proportion of growth. From the graph, it can be seen that due to the almost unchanged slope, there may be a certain relationship between the changes in the final angles 1 and 2.

## 5. Conclusion and future work

In the planar elliptical structure, the length and height are generally increased and the rate of their increase is kept decrease since the angle θ increased.

And for the arched structure opened, the gap length is generally increased and the rate of their increase is kept decrease since the increase of angle θ1. In addition, θ1 is approximately twice and more than the θ2.

In fact, we also see that the changes in height and length are similar, both rising while the speed of ascent gradually decreases.

The significant difference lies in the overall difference of about 5cm in length and height, which proves that a part of this elliptical structure is actually an increase in circular variation.

Correlation between the angle changes and the whole structure in force, is still interest to be found, and is also need to continue focus on to find the utility of them in engineering.

So, to find out the correlation equation of the angle change with the height of the structure is important at the start of the future research. Furthermore, continue to research practical applications of mechanical structures in engineering, as well as how to solve more potential real-world problems and what deeper applications they may lead to behind these problems.

If possible, connect it with motors in the future. At the same time, add some other autonomous control components to complete a series of behaviors or actions, such as completing movements or automatic stretching and contraction.

## References

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