DOI: 10.24904/footbridge2017.09340

ORIGAMI INSPIRED DEPLOYABLE & MOVABLE BRIDGE FOR DISASTER RELIEF

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Summary

Using the latest technical developments in structural engineering, the basic mechanisms of the buckling and post-buckling response of a thin cylindrical shell under torsional or compression loading are reviewed. The deflection response deep into the large-deflection range is considered such that the shell is allowed to fold into a flat two dimensional form, via a mechanism reminiscent of a deployable or folding structure. The critical and initial post-buckling of Origami-folding effects are explored using the concepts of energy minimization and hidden symmetries. The concept is developed using Origami that is applied to a rapidly deployable, foldable, and movable bridge systems for multipurpose uses, predominantly in disaster relief for refugees and displaced people, is investigated. The concept for the structure has been inspired from Origami understanding and applying a scissors mechanism, a principle using linked, folding supports in a criss-cross 'X' pattern as a basic unit in the structural system. We review this new type of bridge system resulting in the Mobile bridge proposition which has the advantages of both simultaneously serving the specific purpose of providing relief for displaced people in times of need and in emergency situations.

Keywords: deployable bridge; scissors-type bridge; emergency bridge; light-weight structure; temporary bridge

1. Utilising the art of Origami in the field structural engineering

Buckling is recognized as one of the fundamental problems of elastic stability because of its significance in the engineering design of, for example, a thin circular cylindrical shell under torsion and/or axial compression will experience a sudden reduction in stiffness at the onset of buckling. The two contrasting loading situations exhibit quite different characteristics of load/deflection response as deformation continues into the large-deflection range. While the former initially results in a highly unstable response followed by re-stabilization as it settles into a localized form of the well-known Yoshimura or diamond pattern deformation, the latter forms similar but oblique shapes which are capable of folding entirely in the axial direction without significant in-plane stretching. Fig. 1 shows the development of the folded form in a paper specimen twisted between two inner plastic mandrels. Following an initial buckling stage that involves both bending and membrane (in-plane) stretching, a pattern resembling an Origami type mechanism is generated. Such folding is prevented in the axially loaded problem which has Yoshimura type pattern due to the significant stretching

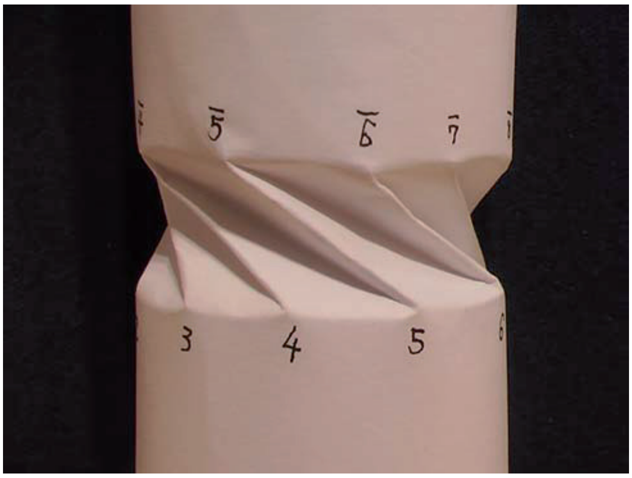

Fig. 1. Twist buckling and the foldable cylinder

Fig. 2. Test of the Mobile Bridge® Version 4.0

occurring at the re-stabilization stage. The framed core of the buckling pattern resembles a part of the pantographic-lift machine which is available to lift up and down a mechanically expanding/folding system along the vertical direction. Folding without stretching is undoubtedly of considerable interest in the field of deployable structures.

2. Test for taking over a river

We review the release of the first test of the full-scale, novel scissors-like bridge structure MB4.0 [2]. The developers at the Institute of Engineering at the Hiroshima University conducted a field test in conditions resembling the real situations of bridge deployment. The test of the MB4.0 over a real river of 17m in width, called the Hongo river, demonstrated its capability for practical use on 24th April 2015 in Fukuyama, Japan.

The MB4.0 reached the other side of the river safely without any technical problems and was operated by a very limited technical crew, as shown in Fig. 2. The total time from the arrival of the MB4.0 on-site to its full expansion was approximately one hour. No work, including preparation of foundations for the other side of the river, was conducted during the test. The deployment of the bridge also did not involve the use of a crane or any other construction machine, which are typically involved in such situations. This is particularly important in time-sensitive situations characteristic of disasters.

In the current research, we are developing the MB4.0 as a type of robotic bridge by improving its mobility and functionality and decreasing its weight. Thus, the MB4.0 has become more transportable and easier to set up at temporary construction sites without any foundation, construction, or heavy machine operations. As a result, it is also much more cost efficient.

3. Conclusions

This paper presents a new design of the deployable and/or folding bridge with scissor structure based on the post-buckling theory for a cylindrical shell using Origami skill in the field of engineering. We applied it to the full-scale MB4.0 with integrated lower deck boards and field experiment related to crossing of a real river in Japan. After demonstrating structural safety of the bridge, we carried out fundamental numerical simulation and experimental testing to investigate the dynamics of the MB4.0.

4. References

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