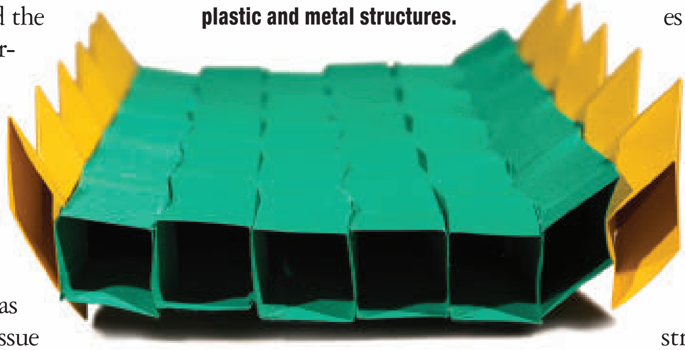
Researchers Unfold the Structural Benefits of Origami



The researchers used several origami zippered tubes to build a prototype paper bridge. They say that the technology could be used to make various plastic and metal structures.

ROB FELT, GEORGIA TECH

ORIGAMI, THE centuries-old Japanese art of paper folding, could hold the key to crafting structures that are physically stable even though they are made from thin, easily transportable materials. An international research team has developed intricately folded paper structures that its members say can be stored compactly and uncoiled to support a significant level of weight.

The team comprises researchers from the Georgia Institute of Technology, the University of Tokyo, and the University of Illinois at Urbana-Champaign, and its members contend that the method could be applied to plastic, metals, and other materials to build, for example, emergency shelters, bridges, furniture, and robotic arms. Their work was published in the October 6 issue of the journal *Proceedings of the National Academy of Sciences.*

The researchers say that the origami structures can be easily stored and transported in their compact, fully folded position and then be unfolded when the time arrives for assembly. The interlocking units could be used to build structures that save lives, provide vital infrastructure, or perform other tasks that researchers have yet to imagine, they say.

"I think we've just scratched the surface," says Glaucio Paulino, Ph.D., A.M.ASCE, a professor in Georgia Tech's School of Civil and Environmental Engineering. "It is a simple idea, but it has tremendous potential."

Paulino authored the team's research paper along with Evgueni Filipov, a graduate student in civil engineering at the University of Illinois, and Tomohiro Tachi, Ph.D., a professor in the University of Tokyo's Graduate School of Arts and Sciences. Paulino began a three-year study in September, funded by the National Science Foundation, to develop additional folding configurations and uses for the technology.

The configuration detailed in the team's research paper is a so-called zippered tube, that is, an elongated hollow rectangular box that folds in a zigzag pattern. The tubes, much like two sides of a zipper, are attached in interlocking pairs, giving them added stability. Pairs can be combined to form larger three-dimensional structures.

The technique used to form each tube is known as the Miura fold. Here a flat surface is folded in straight lines along one axis and in a zigzag pattern along the other, enabling it to be fully collapsed or unfolded in a continuous motion. The method was developed by the Japanese astrophysicist Koryo Miura for deploying of satellite solar arrays.

Paulino says that the researchers tested numerous folding configurations but selected the zippered tube because it maintains its stability when unfolded to any length ranging from its compact, fully folded position to its full longitudinal extension. The zipper configuration enables tubes to better resist twisting and bending, essentially making them structural members that can be stretched or contracted to various lengths without any loss of stability.

"If you're constructing a building, then you only need to worry about one static configuration," Paulino says. "But we needed the origami to be stable in an infinite number of configurations; if a configuration is stable up to only 50 percent deformation, then it might not work."

In the course of manufacturing and testing their paper prototypes, the researchers found that paired tubes could be expanded or retracted simply by manipulating one of their ends and that they were stable even when folded at differing angles. As a result, tubes of different sizes and shapes could be combined to create an array of objects, for example, bridges, towers, and even microscale and nanoscale medical devices.

While the research team developed paper tubes to prove the concept's effectiveness, such structures would have to be made from such stronger materials as plastic or metal if they were intended to have structural purposes. A major goal of the team's upcoming research is to develop and test tubes made from such materials.

Paulino envisions a future in which 3-D printers could be used to manufacture large tubes that would be stored in minimal space and deployed after natural disasters for the construction of emergency bridges, shelters, or canopies. He says that the tube structures could incorporate hinges and additional features to give them more functionality.

Paulino received a $465,000 grant from the National Science Foundation to continue the research. He and his students will further examine the qualities of origami structures by testing additional configurations, building prototypes, and developing mathematical models that describe the structures' behavior.

"With these tubes, we can reprogram them and change their cross sections in many different ways," Paulino explains. "We can have many, many different types of configurations." —DAVID HILL