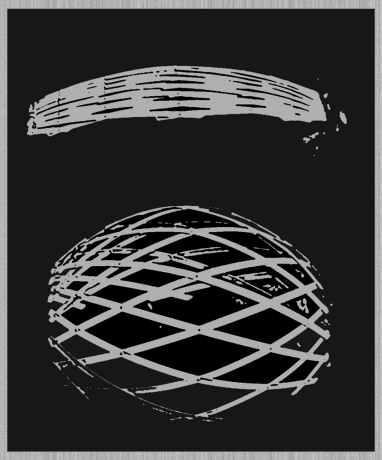

DEVELOPMENT

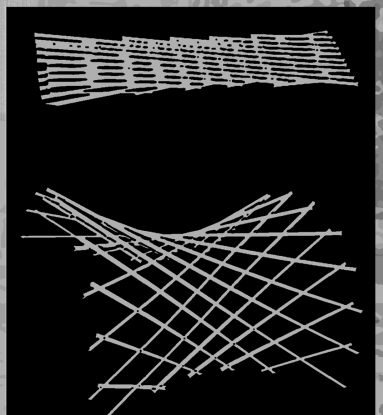

Illustration by Eashwar Minimudi Suresh | 8th sem

03. A Brief Overview of Deployable Structures.

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Abstract :
Deployable-Collapsible structures are unique types of structural systems capable of transforming from a closed configuration to large-span (and vice-versa) enclosing structure. Due to their compact nature, ease of transportation and expansion ratio, these often find use in semi-permanent structures, bridges, emergency shelters and facilities, and also outer space structures. The use of any deployable structure is majorly governed by the needs and the type of deployment required. The types of deployable structures can further be classified depending on the nature of elements that make them up. The article gives an overview of the types and characteristics of deployable structures and provides an insight into the morphology and applications of deployable structures.

Keywords :
Deployable structures, Transformative, Tensegrity

INTRODUCTION

'Adaptable', 'Kinetic', 'Evolving', are some keywords that are critical considerations for contemporary buildings. New techniques and technologies are implemented in facades, building roofs, etc, which allow for the transformation of the building form as a whole or portions of it, thereby creating a dynamic user experience. Deployable-Collapsible structures are unique types of structural systems capable of transforming from a closed configuration to large-span (and vice-versa) enclosing structure. These are exceptional in the sense that they can be rapidly deployed, can be stowed and transported from place to place.
Moreover, these are geometrically designed to be self-stable structures in their closed and open configurations. Some types of deployable structures may exhibit non-linear behaviour, which means that for any small load applied, they have large displacements. This makes them a highly specialised class of structural systems. The article gives an overview of the types and characteristics of deployable structures and provides an insight into the morphology and applications of deployable structures.

USES/ APPLICATIONS

The transformable nature of deployable structures opens up a wide range of possible uses. Due to their compact nature, ease of transportation and expansion ratio, these often find use in semi-permanent structures, bridges, emergency shelters and facilities, and also outer space structures. Depending on the category and type of geometry these structures can be retractable domes, expandable walls, collapsible vaults, etc. Current ongoing research in this field opens up possibilities of many new geometric configurations, which would increase further prospects for the use of deployable structures.

TYPES

In general, the use of any deployable structure is majorly governed by the needs and the type of deployment required. The type of deployment is primarily dependent on the geometric linkage which defines the behaviour of the structure.
(Zhang 2021) classified deployable structures into three types:
Rigid Deployable, Flexible Deployable and Hybrid Deployable structures.
Rigid Deployable structures provide high stiffness ratio and consist of stiff linkages. Image-1 shows an example of a rigid deployable structure.

A flexible deployable structure on the other hand consists of flexible rods, shells and thin cables and is suitable only for one time deployment. The flexible cables are folded to a small volume by external force and these store potential energy within themselves. When this energy is released, the structure expands. This technology is frequently used in solar arrays, solar booms and sails.

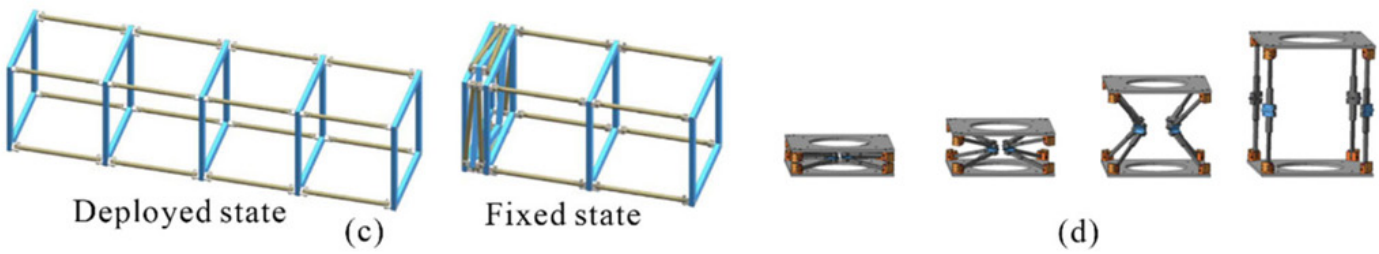

Image 1: Rigid Deployable Structures ; (Source: Xiao Zhang, 2021)

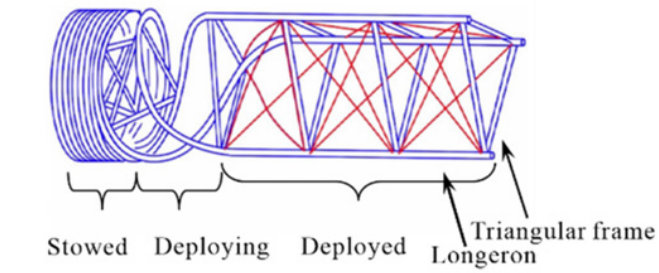

Image 2: Image of a flexible deployable structure ;
(Source: Xiao Zhang, 2021)

The third category is that of hybrid deployable structures. These types of structures consist of rigid linkages with intermediate flexible elements. The rigid linkages provide stiffness and stability to the structure, while the flexible cables allow for folding and add to the lightness.

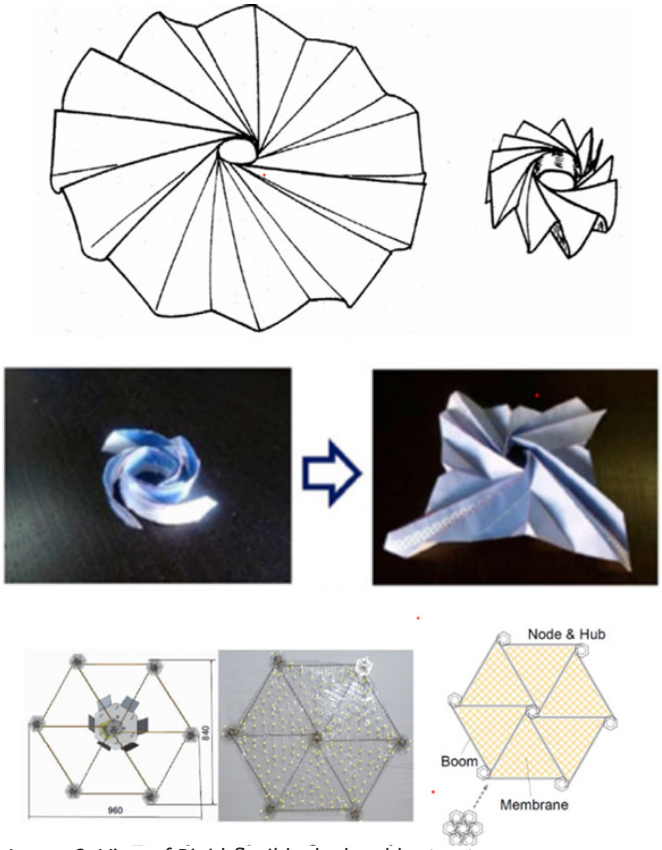

Image 3: View of Rigid-flexible deployable structures
(Source: Xiao Zhang, 2021)

The three types of deployable structures can further be classified depending on the nature of elements that make them up. As mentioned by (Amela Šljivić et al., 2021), they can be further classified into structures composed of bar elements, plate elements, spatial elements such as, pneumatic structures, and combined elements which include bar and membrane or plate elements. The façade of the Al Bahar tower in Dubai is an example that uses combined elements of bar and plate elements, to create an adaptable façade. Deployable structures with plate-like elements often use origami principles to determine the method of folding. Different types of folds can guide different movements. Some common fold types include the Miura fold, the Resch fold, and Yoshimura fold

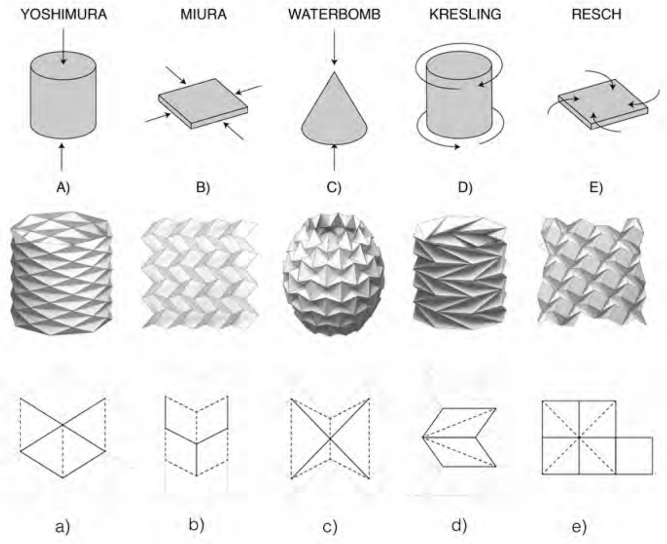

Image 4: Different fold types
(Source :Matthew Gardiner, 2018)

The deployable structures that use the bar elements can be further classified as those using a tensegrity mechanism or structures with scissor linkages. Deployable tensegrity structures contain cables that are in tension and bar elements that are in compression. Folding of the tensegrity structures is primarily dependent on the cables.

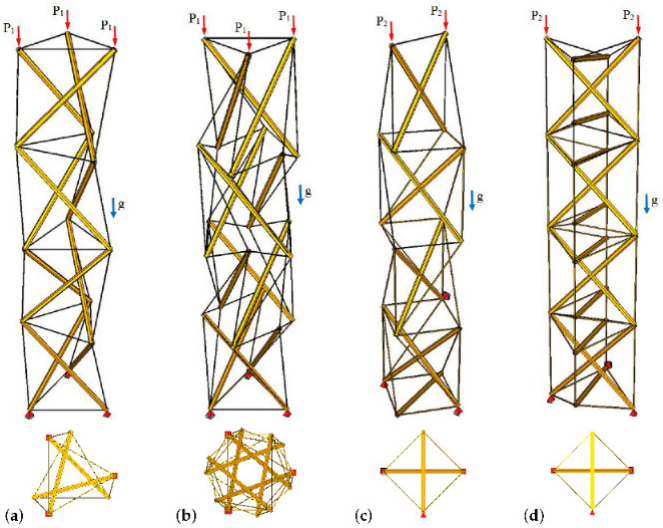

Image 5: Tensegrity deployable structures
(Source: https://www.mdpi.com/2076-3417/10/23/8676)

The deployable structures with scissor linkages are a very interesting classification in the domain of deployable structures. Some of the scissor based deployable structures were developed early on by Pinero and Hoberman. The following image shows a deployable dome made with scissor-based elements by Hoberman. Depending upon the geometry of the linkages, the scissor type deployable structures can fold and move linearly, radially or in a polar configuration.
Different scissor configurations can generate various movement patterns. The section below highlights some examples of buildings, which implement deployable structures in their roof, facades, etc.

Image 6: Deployable dome by Hoberman
(Source: https://www.designersandbooks.com/blog/greg-lynn-book-list-digital-dialogue)

EXAMPLES

The following two examples highlight buildings which use deployable structures, mainly rigid elements, in different parts of the overall structure. An example of a building which uses the scissor bar type of deployable structures is the Olympic Arch at Utah. Also known as the Hoberman Arch, the structure is a massive 72 ft span x 36 ft tall transforming curtain, installed for the 2002 Winter Olympics. The curtain was controlled by two motors of 30 HP each which allowed it to open in 20 seconds. The Olympic arch at Utah, was a key example of a scissor type deployable structure, with eccentric connections, which allowed for the polar movement of the arch. This mechanism is also known as the Iris mechanism

Another interesting example is that of the Rolling Bridge in London by Heatherwick studio. Spanning across the Paddington Basin in London, the concept was to create a bridge that breaks apart or moves out of the way to let boats pass through. The idea was to develop a mechanism for mutating the form of the bridge, rather than fracturing it. Built in 2004, the 40 ft long steel truss bridge can curl up to form a circle, and open to form a full-length bridge in a time span of two minutes. Fixed to only one end of the coast, the bridge consists of eight triangular sections, each with hydraulic pistons, that help open and retract the bridge. The steel trusses form the structural component of the bridge, while the base path is created by timber sections mounted within each triangular section. The deployment of the bridge follows

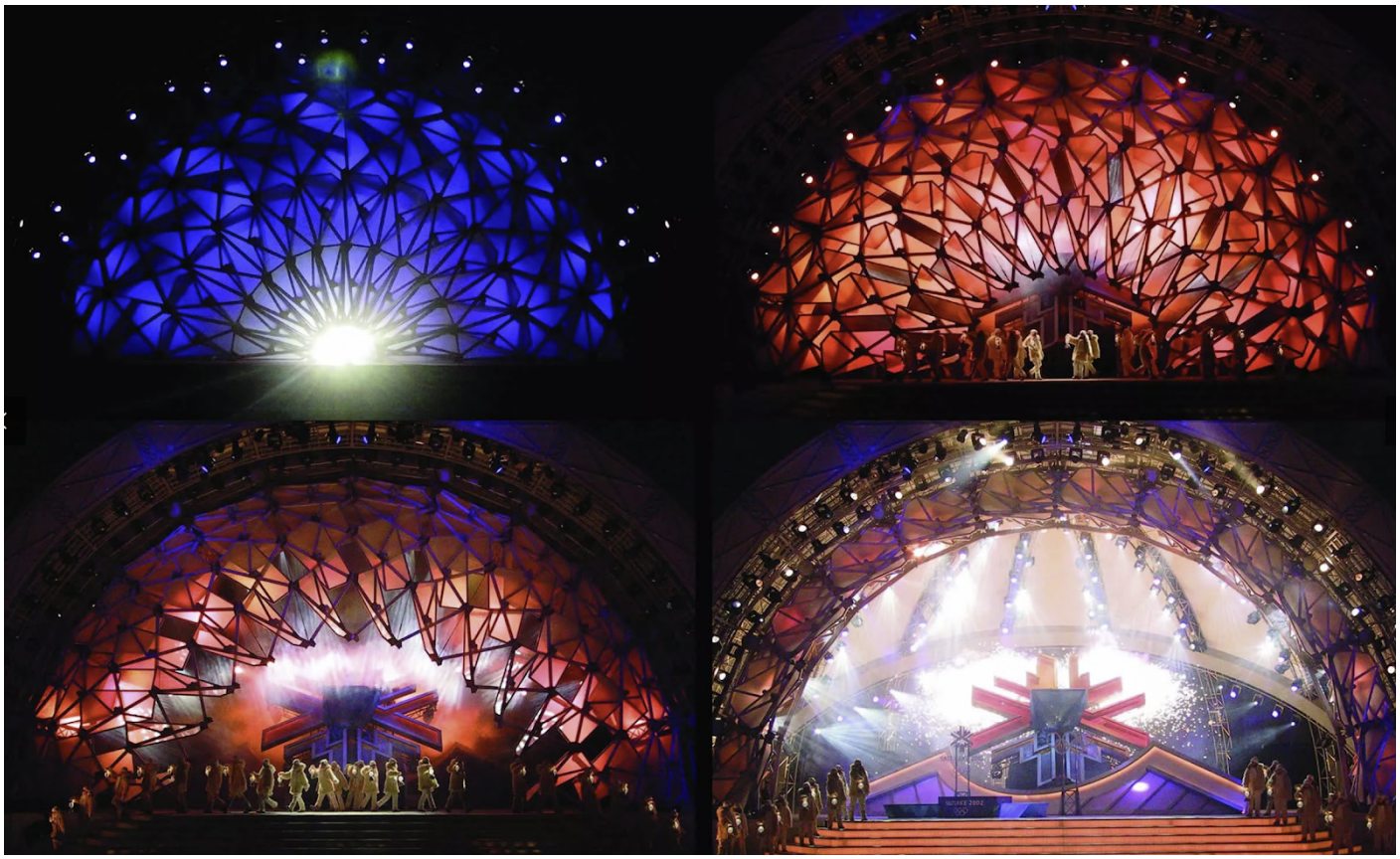

Image 7: View of the Olympic arch at Utah, closed to open configurations
(Source: https://www.hoberman.com/portfolio/olympic-arch/)

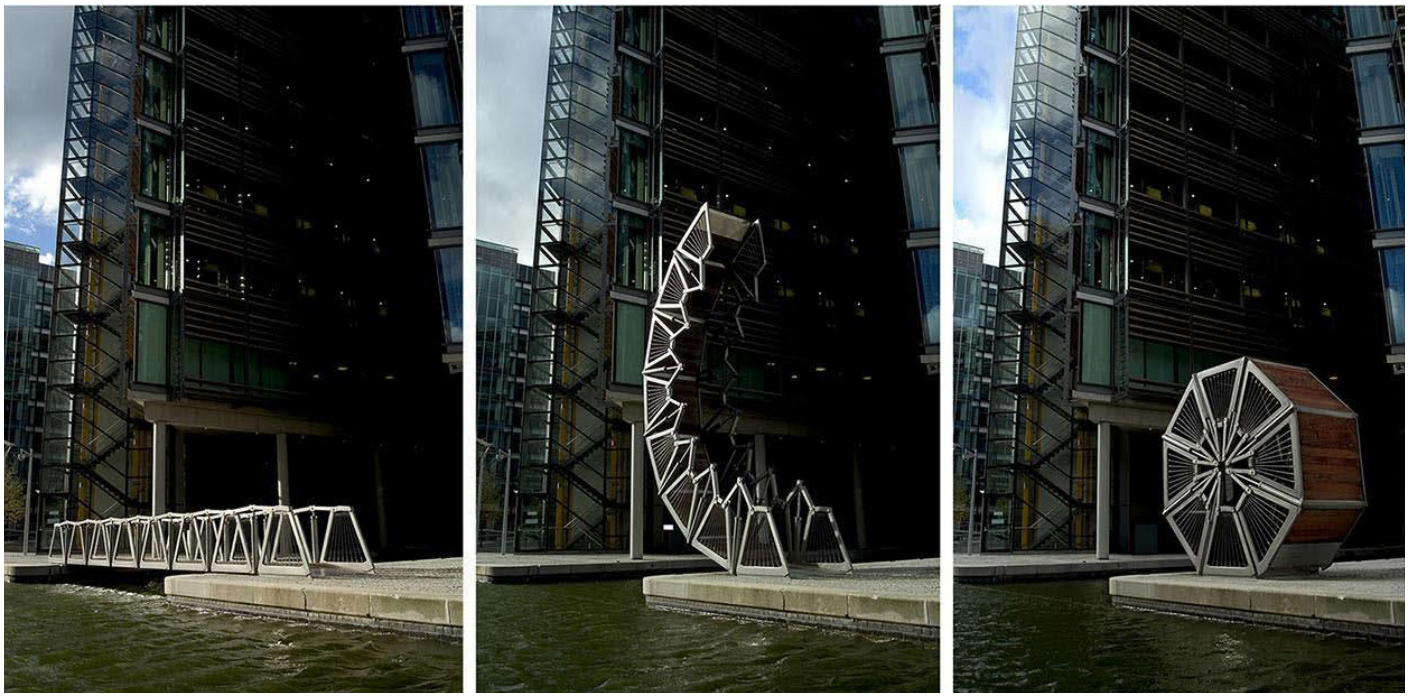

Image 8: View of the Rolling Bridge London in different deployment stages (Source: https://www.heatherwick.com/project/rolling-bridge/)

a polar movement due to eccentric connections between the steel members of the bridge. Each of the trusses is pin-jointed with pistons as a vertical post in the centre of the triangle. This allows for free movement of the steel members, and also creates a lightweight structure. The bridge is an interesting example of an engineering feat in architecture. Image-8 and Image-9, below show the 'Rolling Bridge', London, in its closed, intermediate, and deployed states, and its details.

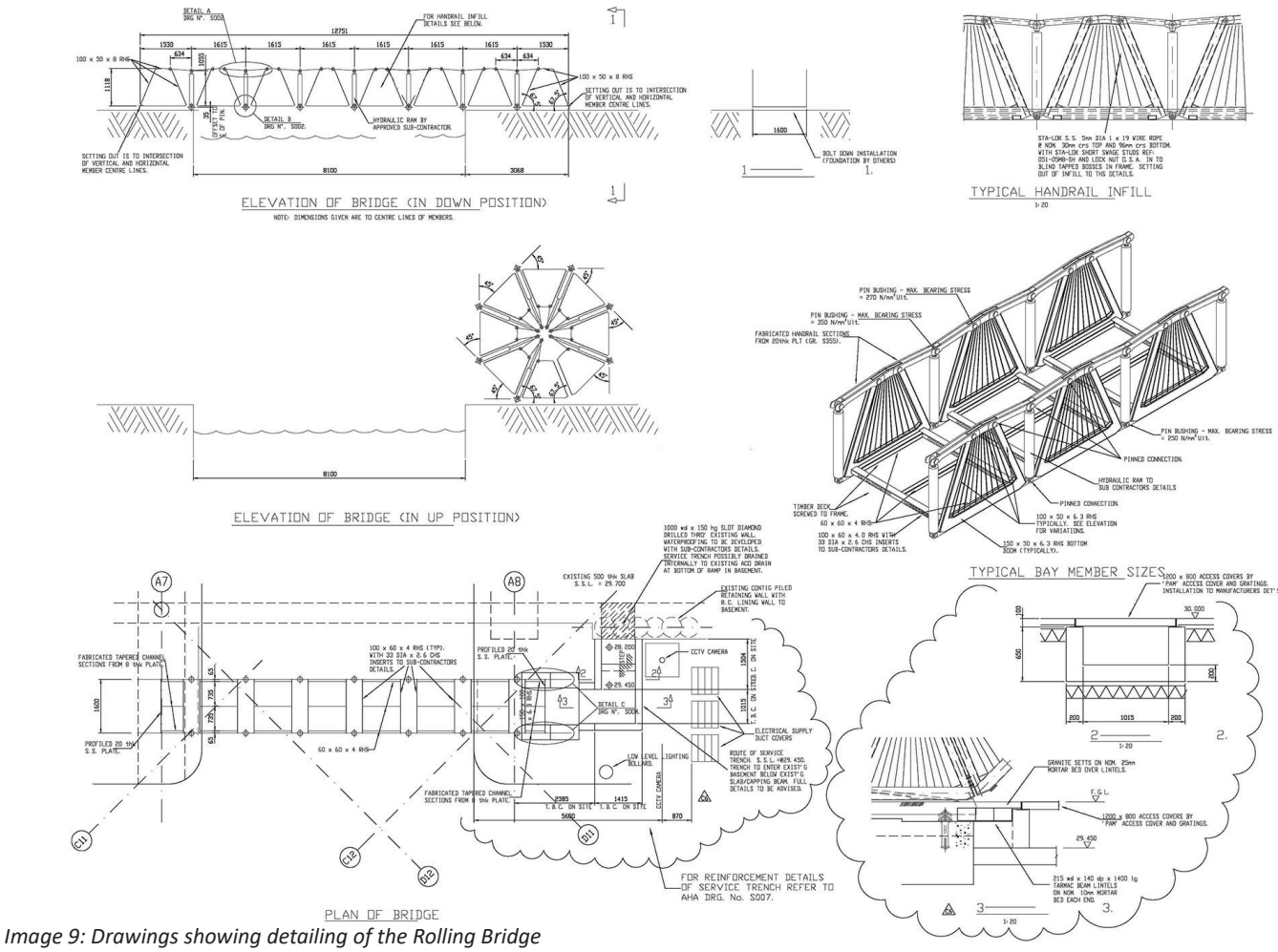

Image 9: Drawings showing detailing of the Rolling Bridge (Source: https://www.heatherwick.com/project/rolling-bridge/)

CONCLUSION

The above examples clearly illustrate how deployable mechanisms can help create adaptable buildings, which generate interesting experiences. The use of deployable mechanisms in buildings and building elements such as facades, roofs, walls, etc. is definitely on the rise due to the multiple possibilities offered by these structures. These structures however do require careful geometric design and advanced structural analysis, as they are susceptible to large deformations under small loads. Their minimum volume, adaptiveness, transportability, and reuse, make them a favourable choice in many fields. Possible parametric variationas in geometries open up a myriad of new possibilities of forms and movement. Overall, deployable structures is an interesting field of special structures that offer a plethora of design opportunities for architects and engineers.

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Anushree is a first-year graduate student at UIUC with a profound passion for architecture. She is particularly interested in the integration of architecture, services, structures, computation, and other related disciplines. Anushree firmly believes that architecture revolves around creative problem-solving, and this aspect excites her the most about her field. The prospect of innovation, exploration, and facing challenges keeps her motivated and eager to tackle new problems every day.

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