Design of a mobile stage-tent transformer

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Abstract
Outdoor festivals are popular and the market for temporary event platforms (both stage floor and covering structure) is growing. However, as the market for festivals and events becomes more competitive, clients are demanding more cost/time efficient structures, and at the same time more spectacular designs. This paper is an illustrated discussion of the design of such a mobile tent construction.

Together with the client the following four design parameters were established, for which an appropriate design solution was found:

1) Striking and unique appearance: the profile should be distinctly different from the standard foldable black box stages.

2) Fast construction and deconstruction time; four people should be able to erect the structure within one day.

3) Foldable; the complete structure should fold and collapse into the restricted volume of 13.5x2.5x3 meters in order to be transported in a trailer.

4) Autonomous; no extra items should be necessary for the erection and functioning of the stage tent. This means that adding extra ballast by filling up water tanks was not an option. Also, additional machinery like cranes or forklifts were assumed not to be available on site.

Keywords: transformer, mobile, temporary, lightweight, membrane structure, metal spatial structure, folding.

1. Introduction

The trailer in which the whole project is transported folds out to become the stage floor. The stage cover is erected as a series of lightweight aluminium trussed arches which support a stretched fabric
skin. Segments of two arches with stretched fabric in between are completely assembled at ground level without the need for heavy machinery or even ladders. The segments can be rotated around two hinges at the front and rear of the trailer. Using electric winches and a system of masts and cables the arched truss segments are rotated around the hinges until they reach the desired position.

The design process has taken three years. It has been a collaboration between one researcher from Delft University and 2 craftsmen with much experience building mobile festival structures. The design process was characterised by a great deal of rapid prototyping (Figure 1 and 2). A total of four prototypes have been 3D printed during different stages of the design. The 3D printed prototypes were crucial in order to:

1) understand the kinematics of the various parts of the structure during the folding and collapsing of the stage-tent.
2) be able to solve the 3D puzzle of fitting all the parts of the structure within the limited volume of the trailer.
3) communicate with the various people who will build parts of the structure or pitch the concept to those who might be interested in investing in the project.

![Figure 1 – 3D printed prototype](image1)

![Figure 2 – 3D printed prototype](image2)

**2. (un)Folding strategy**

The traditional black box stages use hydraulic jacks to unfold and fold their stage floors and superstructures. Such an hydraulic system, although easy to operate, was deemed too high tech and expensive. Instead a system of cables, masts and winches was opted for. The use of the two winches has been optimised as much as possible to ensure that the design premise of construction in one day by a four person crew is satisfied.

The process of first unfolding the floor and then hoisting the trussed arches has been streamlined to ensure that the winches first yield continually until they reach their maximum cable length (Figures 8 to 14). At this point the cables are detached from the floor and connected to the first of the arches. The
winches are then reversed and the cable is pulled back in to hoist the arches (Figures 16 to 20). This method ensures that the cable is never slack. A slack cable could coil onto the winch badly, causing kinks or knots leading to safety risks.

The trusses are laid out in front of the stage and then hoisted. As this is the side of the stage where the audience will be, there must also be enough space to lay out the arches. This means that no extra space is required at the back of the stage and it can be backed right up close to a building. This method also means that the hoisting starts with the smallest trussed arch, thus reducing the initial force required to hoist the superstructure.

The whole superstructure is prone to high wind loading. The toppling of the structure is countered by extra ballast in the trailer floor. The stage construction itself is braced with cables like a trussed beam to make it stiff and bring the pivoting point further from the centre of gravity of the structure (Figure 4). When gusts of over 79 km/h (or Bft 7) are measured the fabric between the last arch and the stage floor is removed to relieve wind loading on the structure.
3. Unfolding sequence stage floor

Figures 6 and 7: The trailer is manoeuvred into the desired spot. Two heavy steel 2D trusses are lowered onto a series of adjustable feet on either side of the trailer. Cables are installed to secure these trusses. The feet are then screwed up to tighten those cable and create a wide and stable footing for the trailer.

Figures 8 to 14: During the unfolding of the stage floor the winches are used to lower the floors one by one in stages. The trussed arches are tied to the folding floors so they unfold with them, like a fisherman’s toolbox.

The floors are hinged so they can fold. Specific corners need to be stiffened temporarily during the unfolding stage using the steel leg that fold out from the floor and one extra cable (Figure 3) The legs remain in this position and land on their footing when completely unfolded.

When floors on both sides have unfolded halfway, one of the aluminium trusses is raised and shored to function as a pole for the winch cable. This allows the floor to continue to unfold without generating excessive tension forces in the steel cable and on the winch.

Most of the legs for the stage floor are tucked away in the floor construction during transport and can fold out during the unfolding of the floors. Only relatively small and light items such as the cables and the feet need to be manually positioned or connected.
Figure 6 – Trailer contains all components

Figure 7 – Side trusses are let down and secured

Figure 8 – Corners are braced as shown in Figure 3 and lowered using winch

Figure 9 – Other side similarly shored and lowered by unwinding winch further
Figure 10 – Mast is erected and shored.  Figure 11 – Unwinding winch further to lower floors to final position

Figure 12 – Legs fold out from floor and land on feet  Figure 13 – Legs are secured with cables
4. Raising the superstructure

Figures 15 and 16: On either end of the trailer are axles which are at this point fitted with heavy-duty steel hinges. From these hinges the first and smallest arched truss is laid out horizontally. The cables are then yielded a little bit more so they can be fitted to this first truss. Now the winch starts winding back up to raise the first arched truss.

Figures 17 to 20: The hoisting will be paused periodically to add the secondary trusses, the cables for the cross bracing and the next arched truss. Once a whole segment has been completed and braced, the fabric can be pulled into the keder profiles on the arches from the sides. The two fabrics meet in the centre and are joined at the characteristic sharp peak.

This process is continued with all trusses.
Proceedings of the International Association for Shell and Spatial Structures (IASS) Symposium 2015, Amsterdam
Future Visions

Figure 16 – The assembled arch is raised by Winding up the winch again

Figure 17 – Secondary trusses and next arch are assembled

Figure 18 – Fabric pulled into keder profile

Figure 19 – Steps repeated for all four arches
Figure 20 – When in final position the superstructure is secured to the floor structure

Figure 21 – Fabric is fitted to close the back

4. Conclusions

The main advantages of this proposed method for raising the superstructure is that the assembly of the arches, the secondary trusses and the fabric happens at ground level, at a safe working height. It also makes for convenient and more healthy working conditions and reduces the required erection time.

The sizes of the various aluminium truss components have been optimised according to three parameters: 1; allowable weight for two people to carry. 2; required strength and stiffness. 3; fitting everything within one trailer.

This collapsible structure demonstrates that it is possible to achieve a more expressive architectural gesture for a mobile stage transformer with an easy and cost-effective construction method.
Figure 22 – Artist impression

References
Figure 22 – artist impression by Rutger Meier; ARM 2014. www.rutgermeier.com
All other Figures by author