ARNDALE BRIDGE – Hyperboloid structures

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In this coursework I will demonstrate how I modeled The Arndale Bridge and how strength is achieved in the bridge through using this model.

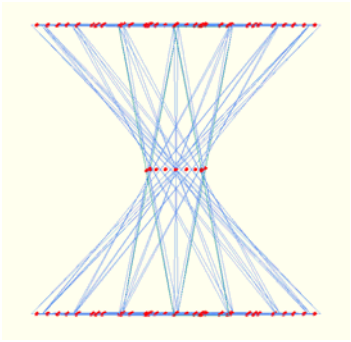
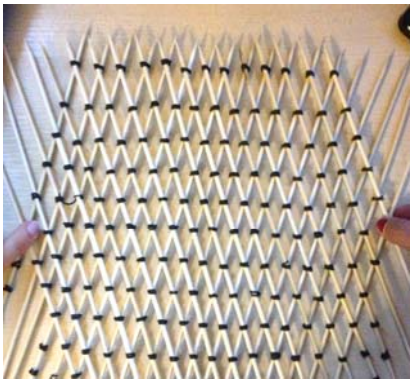


Figure 1: Hyperboloid Model that I created in OasysGSA

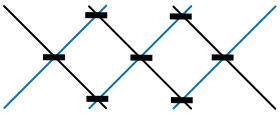
What is a Hyperboloid?

A **hyperboloid** is a **double curved, ruled** surface. This means that the structure is curved in 2 directions which are generated by using only straight members. The two opposing arches balance and strengthen the structure as opposed to one arch which is considerably weaker.

Modeling a Hyperboloid

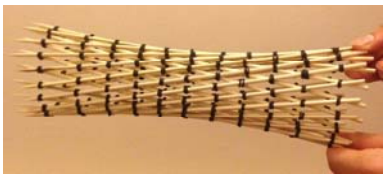


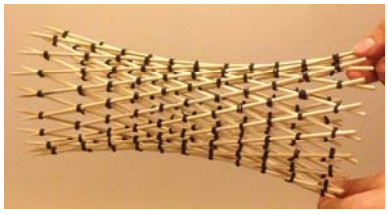
- Sticks were joined together in pairs using rubber bands.
-Further bands were added where skewers crossed as demonstrated in the figure to the right



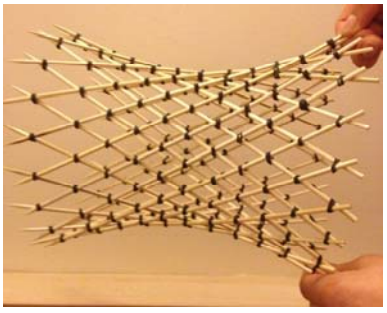
Elastic bands were used to allow the members to rotate relative to each other and were tied loosely to allow movement
-The more rows added creates a stiffer structure
-This creates a mat of 2 layers in a diagrid shape

Connecting the two ends of the net creates the hyperboloid. Without a force applied to it, it naturally conforms to a cylinder-like shape with a very small diameter.





Due to the diagrid nature of the structure, when a force is applied to increase the diameter, the members are forced to twist creating a hyperboloid shape where the centre has a smaller diameter than the ends.



The two opposite curves of the structure create the strength as the bottom curve strengthens and stabilizes the structure by pulling it down. One curve would be weak alone.

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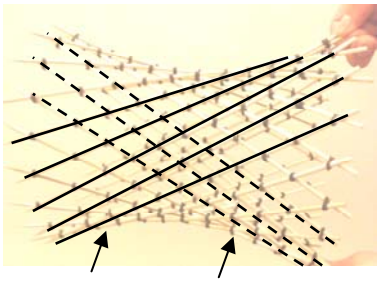
Understanding and Using Structural Concepts

Structural Concept

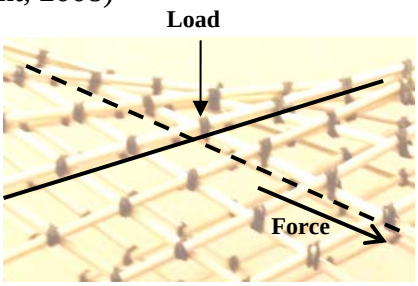


Top beam in compression **Lower beam in tension**

The hyperboloid supports all loads axially in compression and tension rather than bending. The lower, load bearing beam is restrained from deflecting down by the upper, **pre-stressed** beam which opposes this motion by pulling the lower beam up and therefore making it a **stable** structure

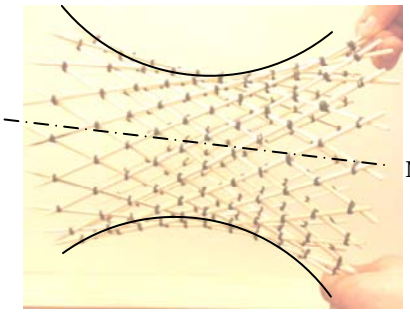
As the 2 layers are opposing directions diagonally **membrane action** is developed as vertical due to the restraining action from the lower beam therefore inducing a lateral force which causes membrane action (frpreinforcement, 2008)

The stress in the structure is constant as vertical load acting on it is only transmitted through **shear forces**. This is because of the torsion of the structure of which when resolved is a vertical component (TUDelft, 2007).



The structure will have **small deflection** as the loads in the structure are transmitted to the support in a direct load path.

The **strength** of the structure increases as I (moment of inertia value) increases; this is achieved through creating a larger diameter and moving the material away from the neutral axis.



Increasing the diameter at the ends of the structure also increases the tension within it therefore making the whole structure **stiffer** and therefore allowing **longer spans**.

Arndale Bridge

This bridge was built to replace the footbridge which was destroyed in the 1996 bomb explosion in Manchester City Centre (Hodderandpartners, 1999).

It is the only bridge in which a hyperboloid is used. (Hodderandpartners, 1999)

The bridge connects The Arndale and Selfridges by fixing the ends of the bridge to either wall.

This hyperboloid is constructed from 18 straight tension rods of 25mm diameter and 110mm hollow compression members.

This shape as many advantages

-as members are in **tension**, the beams can be **thinner** and **lighter** which **lowers costs** but also creates an **aesthetic** and **slender structure**.

Frpreinforcement. (2008). Compressive Membrane Action . Available: http://frpreinforcement.blogspot.co.uk/2008/08/compressive-membrane-action.html . Last accessed 17/02/2013.

Hodderandpartners. (1999). Corporation street bridge, Manchester.Available: http://www.hodderandpartners.com/projects/corporation-street-bridge-manchester. Last accessed 17/02/2013

Toussaint, M. (2007). A Design tool for timber gridshells. The development of a grid generation