MSCOPE Project Proposal
Winter Quarter 2007
Keith Vanderlinde and Milena Tsvetkova

Bridge Exhibit

Type of Project: Hands-On Exhibit

Target Museum: SciTech

Target Audience: Children 7 to 15 years old

The Idea

This project intends to have visitors explore basic physics laws behind structural design. The hands-on exhibit asks children to build a bridge out of a limited number of small elements (ropes and pieces of wood) so that a heavy car can cross a river.

The challenge of solving an engineering problem serves three different educational purposes. Firstly, the exhibit will facilitate children in learning to apply the concepts, principles and processes of technological design[1] – it asks them to identify a design problem, consider limitations in available materials, build a simulation, test it, asses the results and make improvements. Secondly, the hands-on aspect will help children gain an applied understanding of pure scientific concepts such as tension, compression and torque forces and Newton's second law. And thirdly, the modular and open-ended nature of the exhibit intends to develop creative thinking and artistic expression.

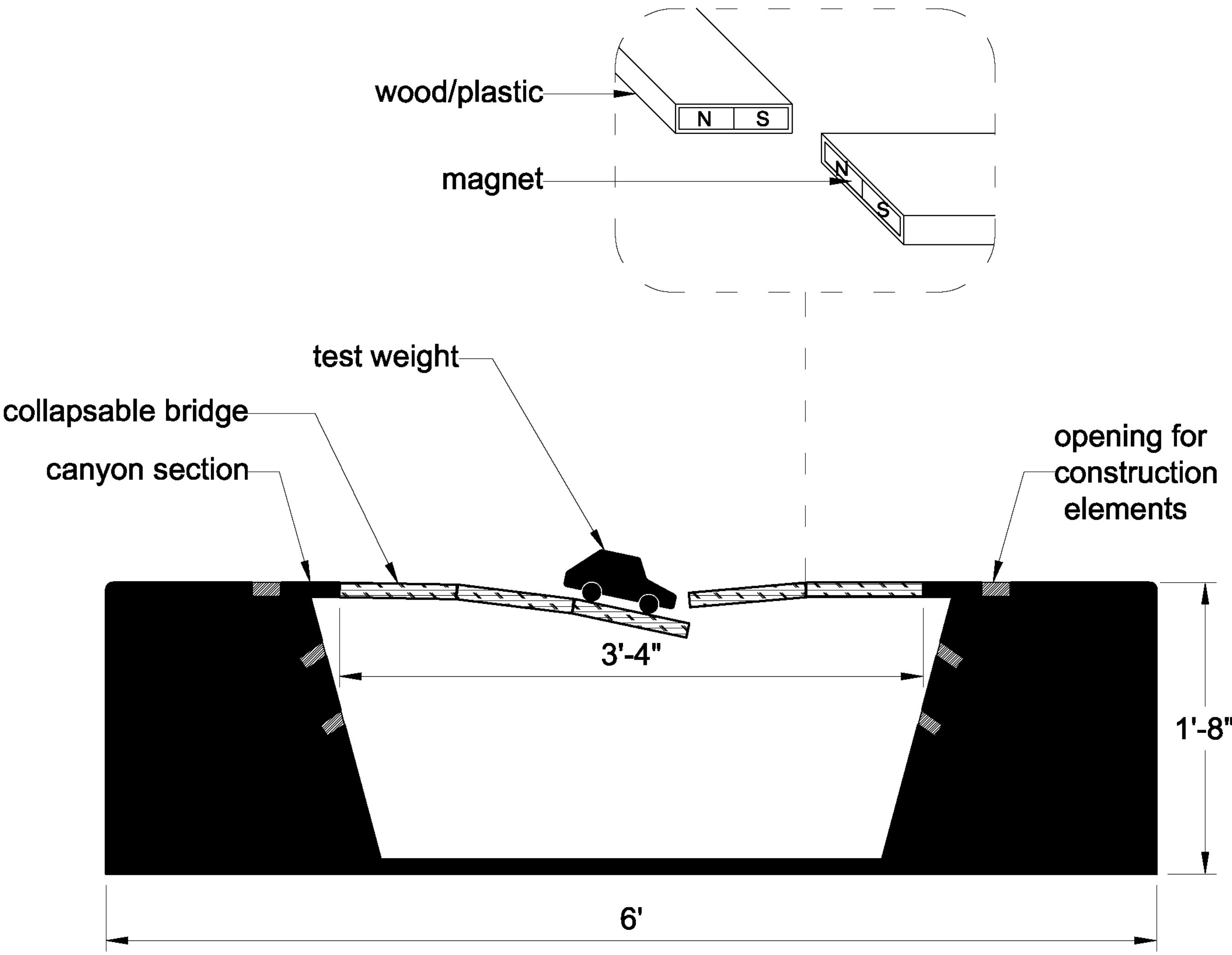
Description

The project consists of a section model of a river canyon (made of heavy-duty foam, fiber-glass resin and pigment), a collapsible bridge (made of wood and magnets), a number of separate string and wood elements, and a weight. If the weight is put on the bridge it collapses. Children have to use the string and wood blocks in a structurally sound and creative way to

[1] As specified in State Goal 11-B for late elementary and middle-school students (Illinois Learning Standards for Science, retrieved from http://www.isbe.state.il.us/ils/science/standards.htm)

Exhibit Base

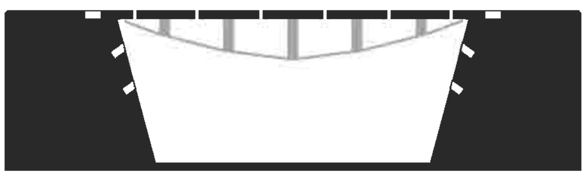
section through canyon



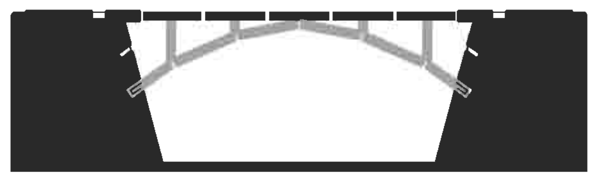
The base bridge will be self-supporting but will collapse under the weight of the car. Children need to use the seperately provided wood blocks and ropes to strengthen the bridge.

How To Make a Bridge

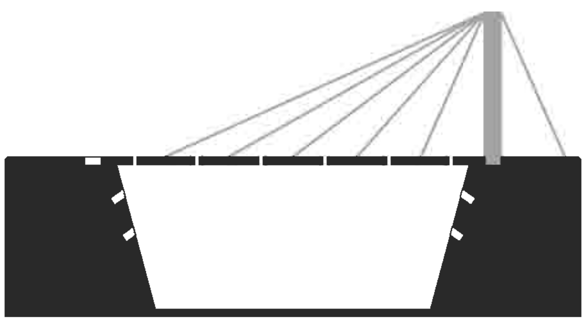
sections through canyon



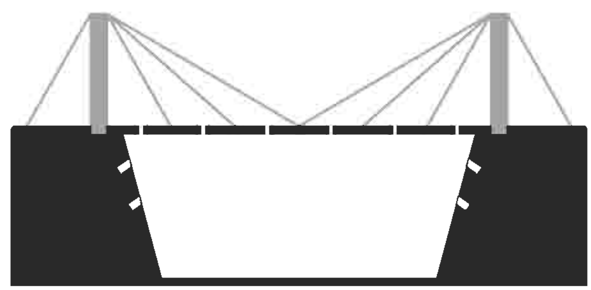
truss



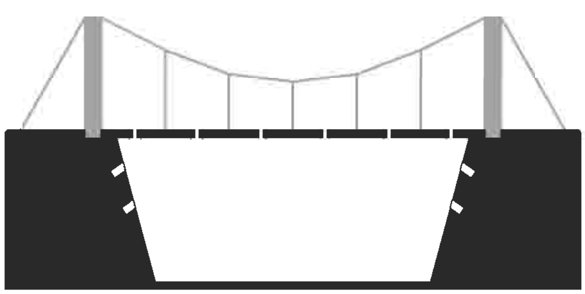
arch



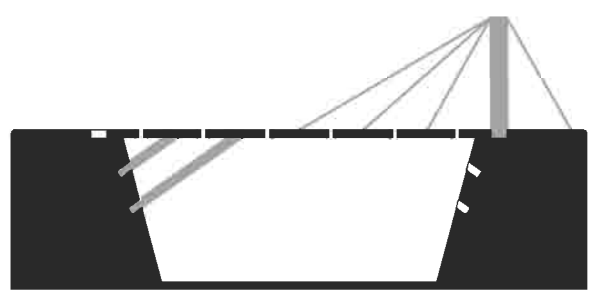
cable-stayed



cable-stayed



suspension



combination

Children will be able to strengthen the bridge by adding a number of elementary blocks (shown in gray). Represented here are only a few of all the possible combinations for them to explore.

strengthen the bridge. The string and wood members will have universal connections and a limited variety of shapes and sizes so that they can be put together in different combinations.

The exhibit will be around 6’x4’ in area. It will allow two bridges to be worked on at the same time. Children can work alone or in groups. The exhibit will be centered around the challenge of building a new bridge that will allow the “car” (the weight) to cross the “river.” In this way, children will also have the opportunity to test the structure they have built.

The instructions in the exhibit labels will explain the physics behind static equilibrium (sum of all forces being zero). They will also show a number of basic designs so that children can start by trying to replicate what is drawn. However, once they gain confidence with the basic principles, it will be clear that there is an unlimited number of design possibilities to be explored. Thus, since the exhibit allows for interpretation at different levels it can potentially engage visitors of different ages, including adults.

Science and Technology Behind the Concept

Building technology combines physics, material science and economic considerations. For example, structural engineers have to design bridges that most efficiently carry loads across long spans. Bridges act as beams. When spanning long distances, the deck bends under load due to compression, tension and shear stress and can eventually fail. The maximum displacement for a beam under single-point center load is given by the equation

$$w_{\max} = w\left(\frac{L}{2}\right) = -\frac{P L^3}{48\,EI}$$

where P is the load, E – Young’s modulus (a property of the material), L – the beam span between supports, and I – the moment of inertia specific to the geometry of the beam’s cross section.

The equation shows that one way to prevent failure is by decreasing the spanning distance i.e. by inserting intermediate supports. This may be very costly for bridges over rivers or great heights. It is normally much cheaper and easier to increase the moment of inertia, i.e. to strengthen the deck itself. The most material-sparing designs use trusses (multiple small members), cables (members in tension only) and arches (members in compression only).

Common Bridge Designs


Box girder bridge


Cable-stayed bridge


Cantilever bridge

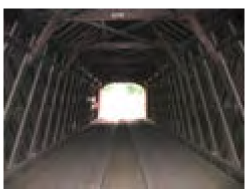

Cantilever spar cable-stayed bridge


Arch bridge


Compression arch suspended-deck bridge


Brunel Truss bridge or lenticular truss


Truss arch bridge

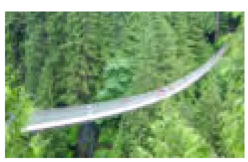

Lattice truss (Town's lattice truss)


Tied arch bridge (Bowstring bridge)


Girder bridge


Plate girder bridge


Side-spar cable-stayed bridge


Simple suspension bridge


Self-anchored suspension bridge


Stressed ribbon bridge


Tilt bridge


Suspension bridge


Vierendeel bridge


Truss bridge

Examples of common efficient bridge designs.
Images and classification from http://en.wikipedia.org/wiki/Bridge.

Evaluation Plan

1. Prototype development and testing. The overall size of the exhibit will be adjusted. Different materials will be considered in terms of safety and durability. Special attention will be paid to the connection details.

2. On-site evaluation of mock-up version. The concept accessibility, the labeling and the technical feasibility will be evaluated.

3. New prototype to reflect findings from on-site evaluation. Level of complexity, size and technical issues will be readdressed.

Connection to SciTech Exhibits

Although SciTech does not yet have a section on building technology, the proposed exhibit can thematically fit among other existing exhibits that relate to the built environment (such as the water tower). Furthermore, the exhibit is in essence a more specific and advanced version of the classic construction games with blocks and bricks, which SciTech offers to its youngest visitors.