Unit

A Structures Unit: Cantilever Bridge

Title

Overview

In this activity you will be an Architect/Civil Engineer. As an Architect/Civil Engineer, you will design and build an efficient cantilever bridge (one that holds the most weight using the least amount of materials).

Standards

The enduring results specify what students should know and be able to do upon completion of the unit, as specified by The National *Technological Literacy Standards*. In this section we would like you to list the standards you are covering in this lesson. An example is here:

Technological Literacy Standards and Benchmarks

A.12.3
A.12.6
A.12.7
B.12.2
B.12.3
B.12.8
C.12.2
C.12.4
C.12.6
C.12.9
C.12.11
D.12.4

Objectives

List the objectives in your lesson. Please use numerical format

1. Understand what forces affect structures
2. Research Cantilever Structures
3. Design, Build, and Test Cantilever Bridge

Teacher Preparation

Read attached materials, check out http://www.pbs.org/wgbh/buildingbig/ website, Individual research

Content Outline

Building Big Web Quest
Watch Building Big: Bridges Video (if you have it)
Rd. Handouts on Cantilever Structures and House on the Rock
Go Over Project with Students
Design Structure, Draw on CADD
Build Structure
Test Structure (Destructive Testing)
Student/Project Evaluation
Structures Term Exam

Activities/Case Studies

Time for Project: Approximately 15 class periods

Cost: Minimal

Assessment

Project Rubric, Structure Terms Test, Student/Project Evaluation, Lab Observations

Resources

Auto CADD, Internet, Building Big Website

Academic Connections

Tied together with Math, Science, and Social Studies.

About the Author

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Design & Engineering
Structures Unit: Cantilever Bridges

Introduction

Construction involves more than building houses-it also includes the building of many other structures. Structures are designed and built for specific purposes. There are many kinds of structures, including bridges, walkways, dams, skyscrapers, and stadiums. One of the most common structures is a bridge. A bridge allows us to move people and materials over obstacles such as rivers, lakes, bays, valleys, and highways. There are several kinds of bridges. These include beam, truss, cantilever, arch, and suspension bridges.

The way a bridge is designed is very important. Bridges must not only be able to hold a lot of weight but also distribute it evenly throughout the structure. Several considerations must be kept in mind when designing a bridge. One of the key considerations is what obstacle the bridge will have to span. The purpose of the bridge is another design consideration. Will the bridge be used for automobiles, trains, or people? Bridges designed and built to carry automobiles must be constructed differently than bridges for trains. Another consideration is how much weight the bridge will need to hold. Finally, safety must also be a design consideration. Local conditions, including weather, must be taken into account when designing a bridge. While proper design is important, bridges must also be inspected on a regular basis to make sure they remain sound.

In this activity you will be an Architect/Civil Engineer. As an Architect/Civil Engineer, you will design and build an efficient cantilever bridge (one that holds the most weight using the least amount of materials).

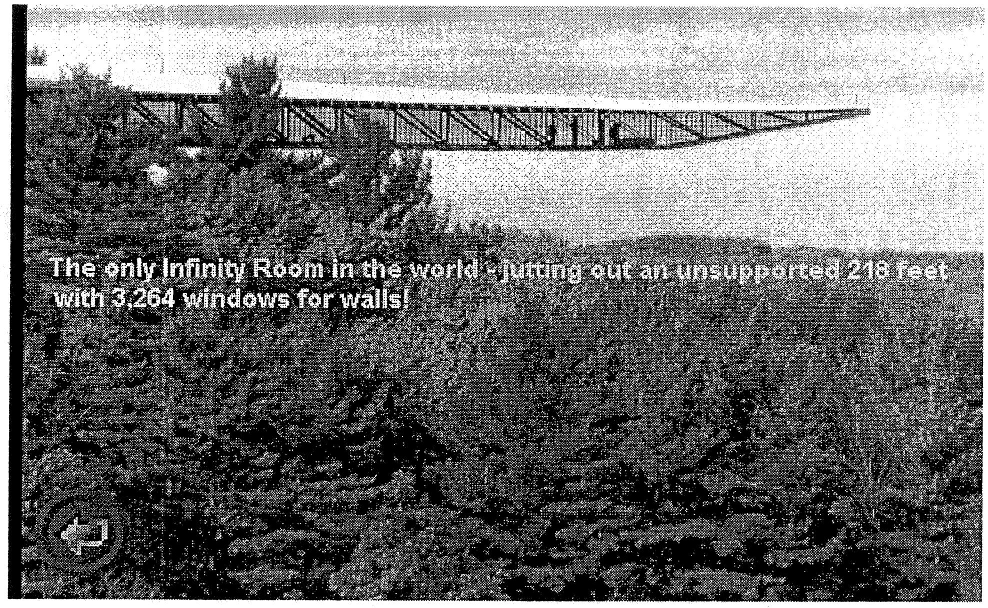
Design & Engineering Students:

You must build a 24" long wooden cantilever bridge according to your plans drawn up by you, the architect. You will be given 196" (8-24" pieces) of approximately 1/8"x1/8" red oak.
You do not need to use all of the materials given to you. Your cantilever bridge will be tested by applying a load to it until the bridge fails (destructive testing). The load then will be weighed and the efficiency will be calculated by dividing the load by the amount of wood (linear inches) used.

Problem:

* Design (2 different designs, 1 final template/drawing) and build a cantilever bridge that is as highly efficient as possible. (An efficient bridge is one that will hold the maximum weight with the minimum amount of materials.)
*The bridge must be 24" long +/- 1/4".
*The bridge must have a 7"x5" base +/- 1/4".
* The bridge must be able to support a 4"x4" block 20" from the base.
*You will be given 196" (8-24" pieces) of 1/8"x1/8" red oak.
*All material is not created equal. Just as in real life, all of the materials that you will get will not be of the same quality. Some red oak sticks may be a little thicker or stronger than others. Some may not be as structurally sound. You must overcome these "natural" challenges and build a successful cantilever bridge.

Equipment/Supplies:
Auto CADD
Drafting Equipment
Drawing Paper
196" (16') of red oak
Wood Glue
Band Saw
Jig Saw
Hand Saw/Exacto Knives
Masking Tape
Pins
Wax Paper
Cardboard
Load-Metal, Sand, Weight
Scale



Specifications:
2 different drawings/designs of cantilevers done on Auto CADD.
Cantilevers must be drawn 1/2 size, and as Multi views. Drawings must have how much material will be used.
After 2 multi views are completed, use best one to complete a full size template drawing (by hand)
Use template drawing to build cantilever
The bridge must be 24" long +/- 1/4".
The bridge must have a 7"x5" base +/- 1/4".
The bridge must be able to support a 4"x4" block 20" from the base.
You will be given 196" (8-24" pieces) of 1/8"x1/8" red oak.
Glue joints must not be longer than 1/2"
Structural members are not to be glued together to increase their cross-sectional area. Structural members are the supports at the top and bottom of the bridge.
Students will work by themselves. (1 student per cantilever bridge)
The bridge will be tested by applying a load until the bridge fails (destructive testing). The load will then be weighed and the efficiency will be calculated by dividing the load by the amount of wood used.

Process:

1. Watch Building Big: Bridges Video. Type a 1 page summary of video (12 pt.).
2. Rd. House on the Rock History and information about cantilever structures.
3. Complete Building Big Web Site Activity and Assignment
4. Hand Out Structures Unit: Cantilever Bridges, go over as a class.
5. Using what you've read and learned, design 2 different cantilever structures on Auto CADD, include how much material (in linear inches) will be used. Drawings will be multi views. (make sure that you have a way to fasten both sides of bridge together). Keep in mind the 4 types of stresses.
6. Print and Show instructor your drawings. Get drawings approved. Choose 1 drawing to make a template drawing from.
7. Draw template drawing of cantilever bridge full size on graph paper. Include how much material will be used (linear inches) on template.
8. Show instructor your final design. Get the okay to start constructing bridge.
9. Get a piece of cardboard as well as a piece of wax paper. Tape your design in the middle of the cardboard and then tape the wax paper over your design.
10. Obtain 196" of red oak wood from instructor. First come, first served on the building materials.
11. Using your drawing as a pattern; measure and cut the bridge members to the correct size. Be sure to measure twice and cut once. You only get 196" of material and bridge must be 24" long, have a base of 7"x5". Also remember the cantilever bridge must hold a weight block which is 4"x4" , 20" from base.
12. Start gluing your bridge together. Use masking tape or pins to hold it together while it is gluing up. Glue should only be used at the joints of the bridge members. If glue is used in places where not needed, bridge will be disqualified.
13. Turn in completed cantilever bridge and the 2 different designs and template drawing of bridge for a grade from the instructor.
14. Measure linear inches, Weigh bridge, Test bridge (The bridge will be tested by applying a load until the bridge fails-destructive testing), determine bridge efficiency. Turn in bridge efficiency for a grade.
15. Take an Assessment on what you've learned in the Structures unit.

Grading:
Students will be graded on the following:

Design-2 designs, Multi view drawings are 1/2 size and neat. Include lineal inches.	10	8	6	4	2	0	
Template Drawing-Full size drawing on paper Neat, professional looking. Drawn out well	10	8	6	4	2	0	
Craftsmanship-bridge looks professional, sides are identical, no excess glue, clean cuts, matches design Within Measurement limits	15	12	9	6	3	0	
Bridge Efficiency-best bridge efficiency to worst (lineal inches to weight held)	20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5						
Bridge Efficiency Sheet-filled out correctly, turned in	5					0	
Work Ethic, On Task, Problem Solver, Behavior	20	17	14	11	8	5	2
Total Points:	**/80**						

BRIDGE DESIGN

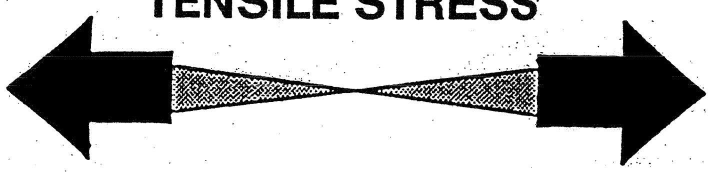
Can you believe people built bridges before they built houses? **It's true----.** Because our prehistoric relatives wandered around looking for food, they didn't even think about building houses. However, to wander very far, they did need to build bridges across rivers and streams.

Nature provided the first bridges. Trees that had fallen across streams, rock stepping stones, and hanging vines were among the choices of materials.

Every bridge ever constructed had the same 4 stresses to overcome:

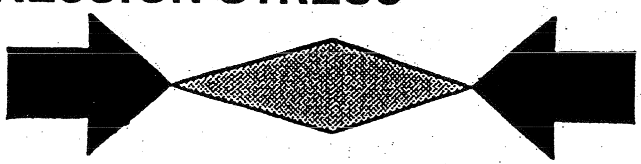
Tensile Stress
Compression Stress
Shear Stress
Torsion Stress

TENSILE STRESS



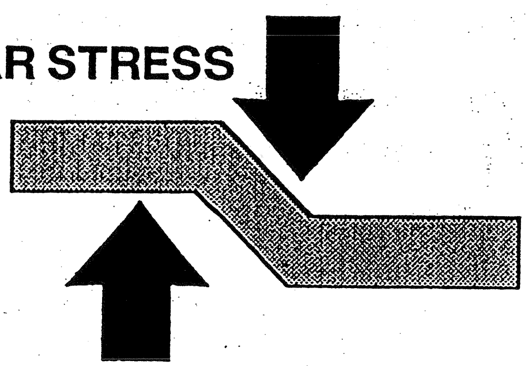
Forces that try to stretch material and pull it apart.

COMPRESSION STRESS



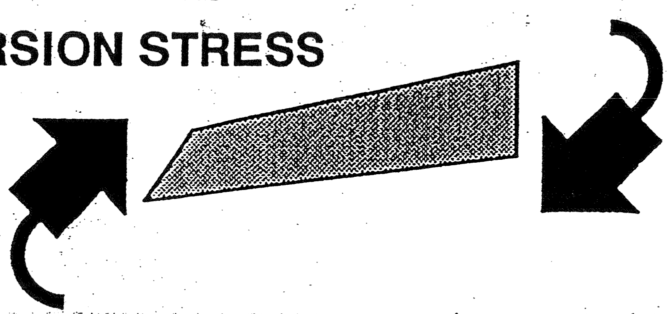
Forces that try to push or squeeze material together.

SHEAR STRESS



Forces that try to make materials tear and slide by each other.

TORSION STRESS



Forces that try and twist and bend material.

BRIDGE PROBLEMS

Many problems must be looked at before a good bridge can be designed.

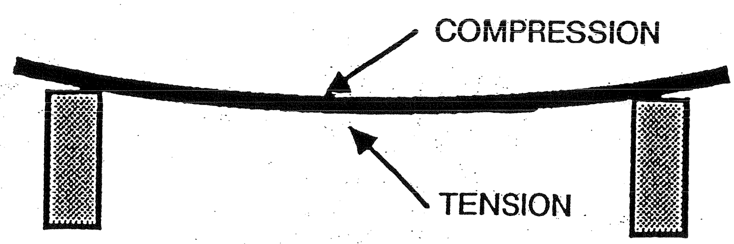
Even professional bridge builders make mistakes. Those mistakes can cost human lives and great amounts of dollars.

In 1940, a suspension bridge that had been built across the Tacoma Narrows in Washington State blew down in a wind storm. The bridge had been called "Galloping Gertie" because it moved and twisted so much in the wind.

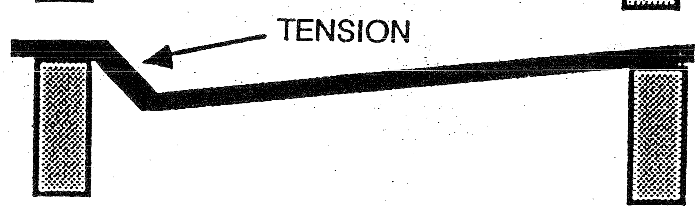
Many lives were lost in Kansas City when an indoor walkway collapsed and fell on people below.

All of these disasters happened because designers used the wrong materials and failed to look at all the stresses on the bridges.

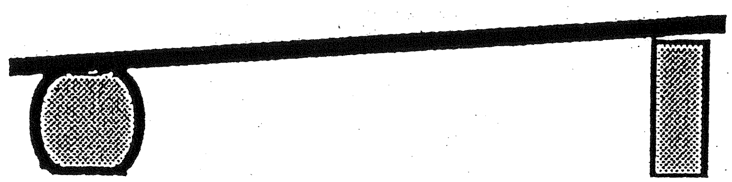
BENDING
The weight of the bridge and the load on the bridge caused it to sag. The materials on top of the bridge compress Tension forces act on the bottom.



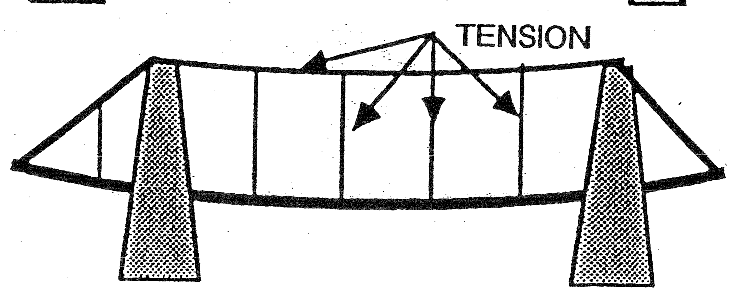
SHEAR
The weight and load of the bridge make the materials slide by each other. Eventually they tear apart.



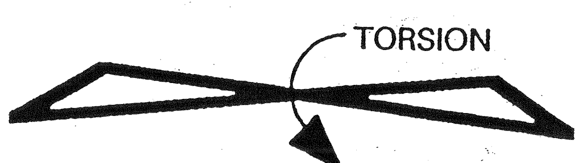
COMPRESSION
Bridge piers may buckle under the weight.



STRETCHING
Bridges that use cables sag when the cables stretch.

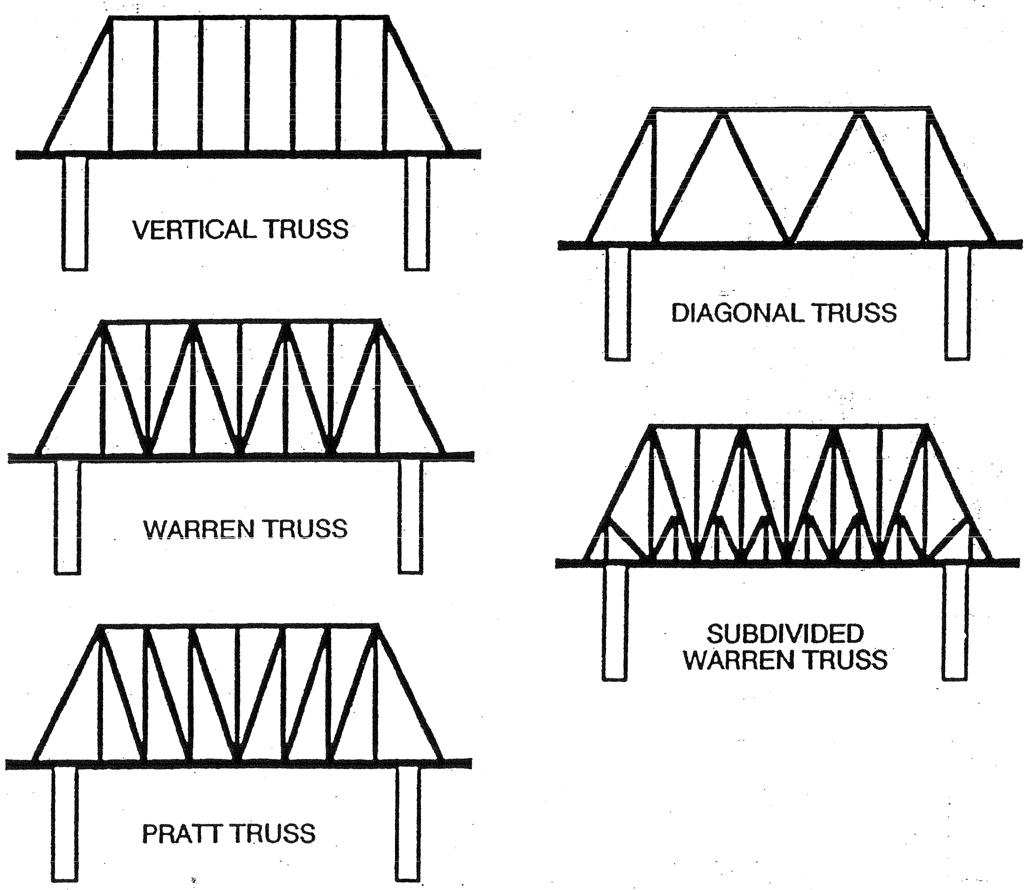


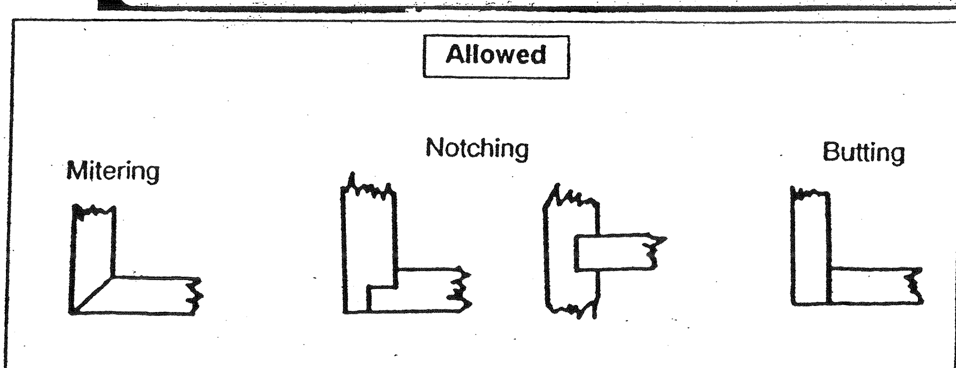
TWISTING
Some bridges will twist when traffic weights are not the same on both sides. The wind will also cause twisting. Torsion forces act on the point being twisted.

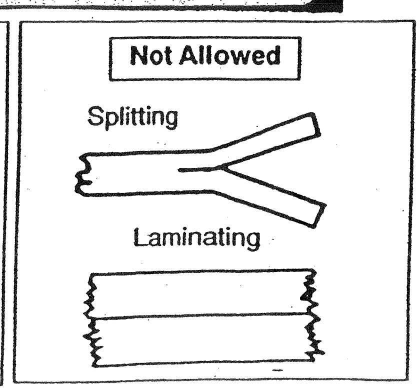


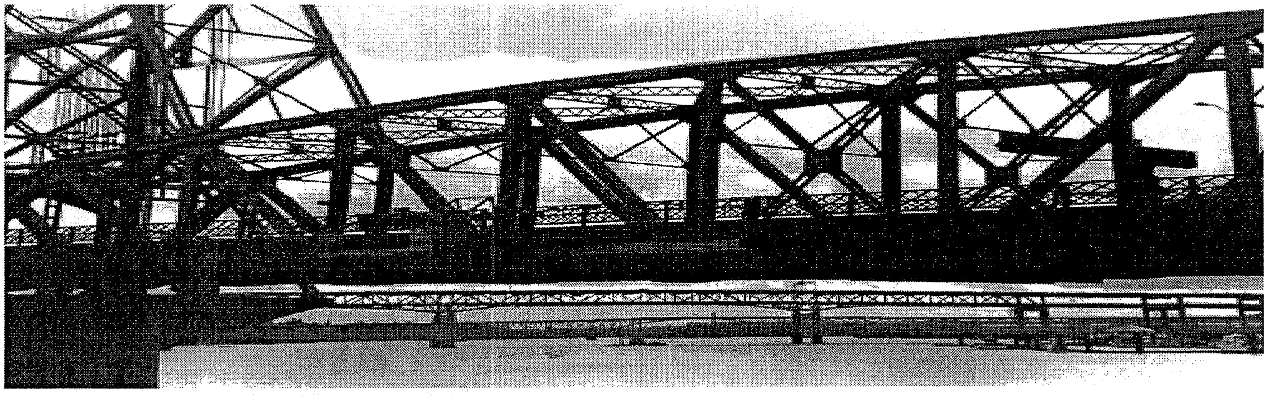
TYPES OF TRUSS BEAM BRIDGES

There are many different types of designs used in the truss beam bridge. Every design uses a series of triangular shapes to help distribute the load.









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Bridge Building Efficiency & Grade Sheet
Complete top portion of this sheet on test day

Total linear inches of bridge: ______________________

Weight your bridge held before destruction: ______________________

Total bridge efficiency: ______________________

Efficiency = **Weight your bridge held** / **Linear Inches**

***Weight must be in pounds**

Grading:
Students will be graded on the following:

Design-2 designs, Multi view drawings are 1/2 size and neat. Include lineal inches.	10	8	6	4	2	0	
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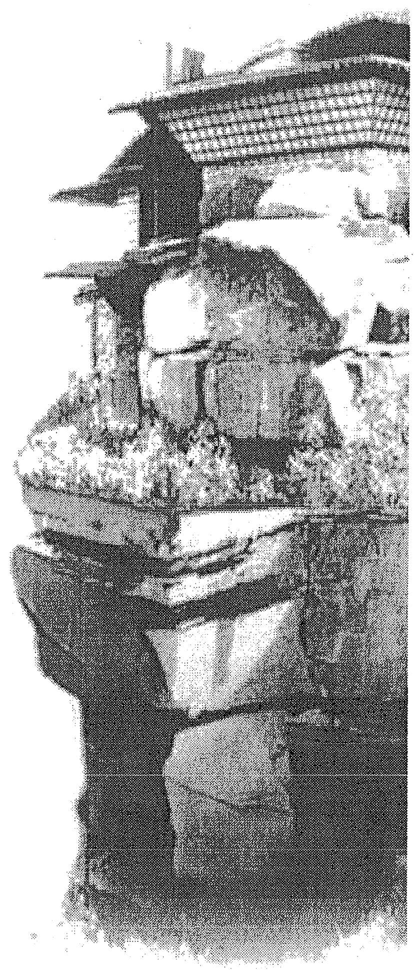
Total Points: /80

House on the Rock

Field review by the editors of roadsideamerica.com

Spring Green, Wisconsin



Alex Jordan, Jr. wanted to teach Frank Lloyd Wright a thing or two about architecture. The lesson started years ago.

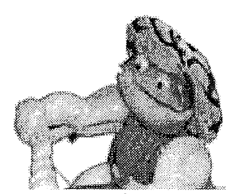
Jordan's dad, a budding architect, had been dismissed at Wright's Taliesin home, near Spring Green, with the declaration, "I wouldn't hire you to design a cheese crate or a chicken coop." Soon after, the senior Jordan chose a pinnacle rock south of Taliesin to build a parody of Wright's fancy-pants architecture, a strange "Japanese house." The ceilings were dangerously low (padded now to accommodate tourists) and the structure seemed to cling precariously to the odd contours of the rock.

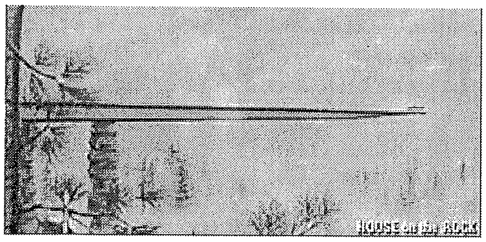
The **House On The Rock** opened to the public in 1961. Today, it is only a small portion of the magical collection that spits in the eye of Mr. Big Deal Dead Architect. When Alex Jordan, Jr. took over the project from his dad in the 1940s he never dreamed where it would end, but with a half-million visitors a year at $15+ a head, it probably won't end anytime soon.

Big pseudo-oriental serpent planters greet you at the entrance and line the drive. Fake palm fronds lend shade to areas around the House. At the ticket window, cautious old people ask, "How many rest stops again?" The tour is self-guided, rumored to take four hours, and not air-conditioned. No amount of mall-walking prepares you for the strenuous, humid, HOTR experience.

The house itself is a claustrophobic shamble through darkened dens and hallways lit by Tiffany lamps. An automated band plays *Bolero*, the first of some thirty-five music machines on the route. There's oriental art, low ceilings, big fireplaces, and carpeting on everything. Was this place designed to be the ultimate bachelor's love nest?

Your climb to the top of the House begins. Waddling camcorderists clog the many choke points on landings and corners. Children are getting antsy; older people stand in the darkness and wheeze. The **music machines** in the House play incessant make-out music: *Harbor Lights*, *Hungarian Rhapsody* and *Love Theme from The Godfather*.





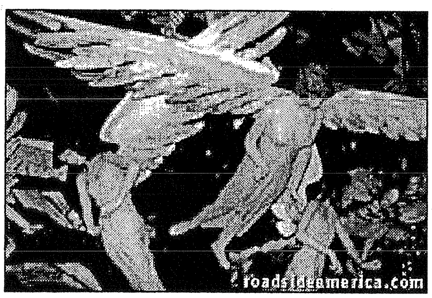
The Infinity Room

Once you get out of the House the fun really begins. The **Streets of Yesterday** building is an indoor recreation of some murky Victorian era. Here, coin-operated music machines abound. Robotic fingers and invisible lips start at the drop of a token. We wonder -- are those magnificent instruments really being played, or is this a tape?

Next is "**Heritage Of The Sea**." This three-level blimp hangar-of-a- room is dominated by a 200-foot long sea monster battling a giant squid. Ship replicas and other flotsam line the ramp that climbs to the top of the chamber. People grip the railing, fixing their sights on the exit, far above.

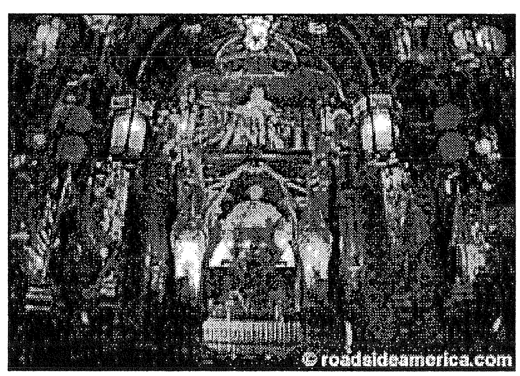
Jordan's creations rivet visitors. "It must've cost him a million dollars." "No, no, he was an genius, an eccentric genius." "And they keep saying he was a poor man." "Well he never had any in his pocket since he was always buying things."

The next room has a display of Santa Claus items. And there's a rest area! Old people buttonhole employees and ask over and over "When is the next stop?" Then they start trying to get out. "When is the next exit?"



The **Carousel Room** wakes you up with a cacophony of music. The 239 carousel beasts, collected from around the world, are half-human and demonic looking; a runaway circus from Hell. Hundreds of topless mannequin angels hang from the walls and rotate overhead. The room contains 182 chandeliers. Exit via an open dragon mouth, and walk down its red shag-carpeted throat. More music machines suck tokens from the surviving oldsters, giving them an excuse to stop.

Next is the **Organ Room**, crisscrossed by catwalks and affording all possible camcorder angles of the huge theater organs, giant copper vats, and immense red glass chandeliers. After this, another exit point/grill/gift store/arts village store, with another hour advertised ahead of you. People may have been here for days. Some are dizzy. "Haven't we seen this before?" "Your grandma's gotta sit down."



We stagger to the **Cannon Room**. Camcorders have exhausted their batteries. Too bad, because this complex is dominated by the world's largest cannon, a weapon so absurdly large that the room had to be constructed around it. The **Doll Room** and **Circus Room** are a weary blur; we finally hobble to the welcoming glow of the gift shop.

Despite the globe-trotting aura of the collection, 'ordan hated to travel and never left the country. He died in 1989, at age 75. The House continues under new management, smartly adding to the collection each year. But Jordan still seems the spiritual caretaker of HOR. A guide tells us that he had one girlfriend for 45 years who inherited most of his fortune, but who knows what to believe with this guy? He was 6'4", weighed over 200 lbs., and liked the coziness of the House On The Rock. It *had* to be a make-out pad.

(**The House On The Rock:** On Hwy. 23.)

The Rock in the House* | *The Forevertron* | *Road Cheese Hypertour: Day 2 - update

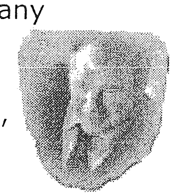
Hotel Reservations

- Welcome
- Attraction
- Admission
- Visitor Information
- History
- Photos
- Christmas
- Floral Displays
- Motorcoach
- Inn
- Resort
- Golf
- Maps
- Area Information
- Contact Us
- Reservations

History

History of the House on the Rock

During the 1940's, a man named Alex Jordan discovered a 60-foot chimney of rock in the beautiful Wyoming Valley. It was then he decided to build a house on the sandstone formation called Deer Shelter Rock. Jordan built the house as a weekend retreat and never intended it to be a tourist attraction. However, people kept coming to see the architectural wonder they had heard about. Jordan eventually started asking for 50 cent donations. That was only the beginning. The 14-room house is the original structure of what is now a complex of many buildings, exhibits and garden displays.



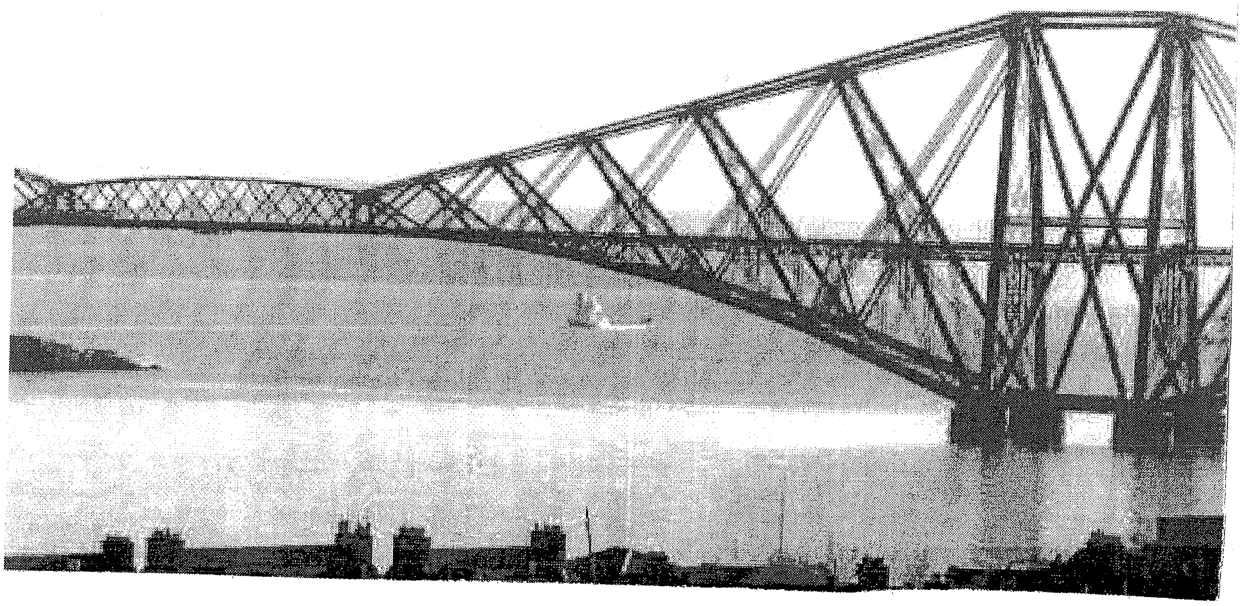
Alex was a collector all his life and enjoyed visiting museums; however, he did not want The House on the Rock to be a museum. He intended it to be much more than that. Though parts of the collections could have easily found their way into museums, The House on the Rock is more of a trip through the wild and fantastic imagination of Alex Jordan than a visit to a dusty, lifeless museum.

In December of 1988, Alex sold The House on the Rock to longtime associate Art Donaldson, a collector and a businessman who shared his broad interests. Alex remained at The House on the Rock as Artistic Director until his death on November 6, 1989. Art Donaldson continues to own The House on the Rock and builds on Alex's dream of expanding and entertaining visitors from all over the world. Alex continues to be in his own words, "Present but not voting".

[Welcome] [Attraction] [Admission] [Visitor Information] [History] [Photos] [Christmas] [Floral Displays] [Motorcoach] [Inn] [Resort] [Golf] [Maps] [Area Information] [Contact Us] [Reservations]

Cantilever
Beam or structure that is fixed at one end only, though it may be supported at some point along its length; for example, a diving board. The cantilever principle, widely used in construction engineering, eliminates the need for a second main support at the free end of the beam, allowing for more elegant structures and reducing the amount of materials required. Many large-span bridges have been built on the cantilever principle.

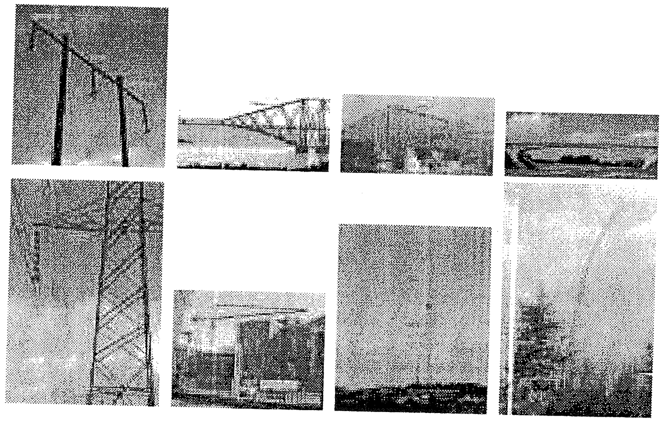
A typical cantilever bridge consists of two beams cantilevered out from either bank, each supported part way along, with their free ends meeting in the middle. The multiple-cantilever Forth Rail Bridge (completed 1890) across the Firth of Forth in Scotland has twin main spans of 521 m/1,710 ft.

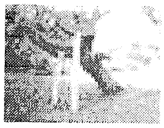


Cantilever is a clumsy word, reflecting a basic problem for designers - how to achieve a satisfactory appearance from a bridge which includes two types of structure, cantilever and suspended span. The requirements of these are completely different. Perhaps only on the grand scale of the Forth bridge can the builders get away with it. On a smaller scale there must be compromises.

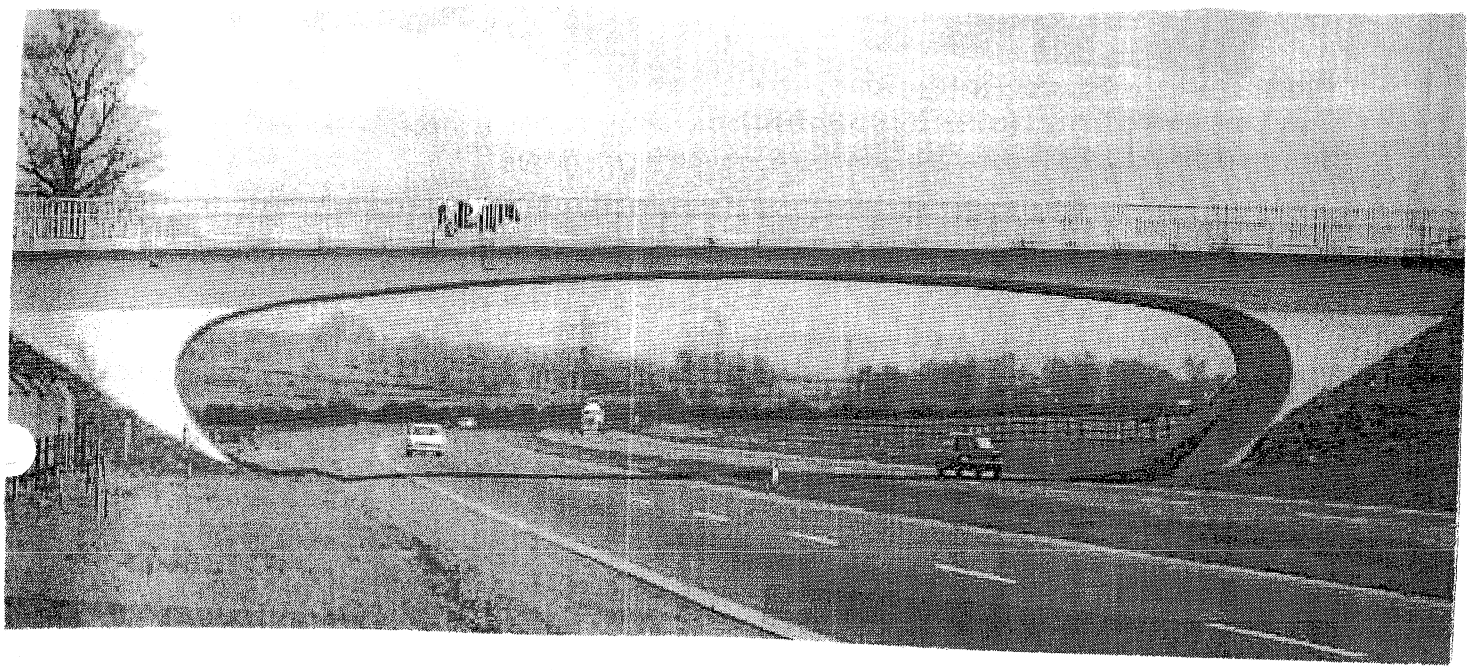
Just as as a great medieval cathedral can include several different styles, something that would look silly in a small house, so the Forth bridge is big enough that the eye can move from the huge cantilevers to the suspended spans, which are sizable bridges in their own right, and not be too offended. It is in the smaller cantilever bridges, such as the ones over motorways, where subterfuge is needed to get a good shape.

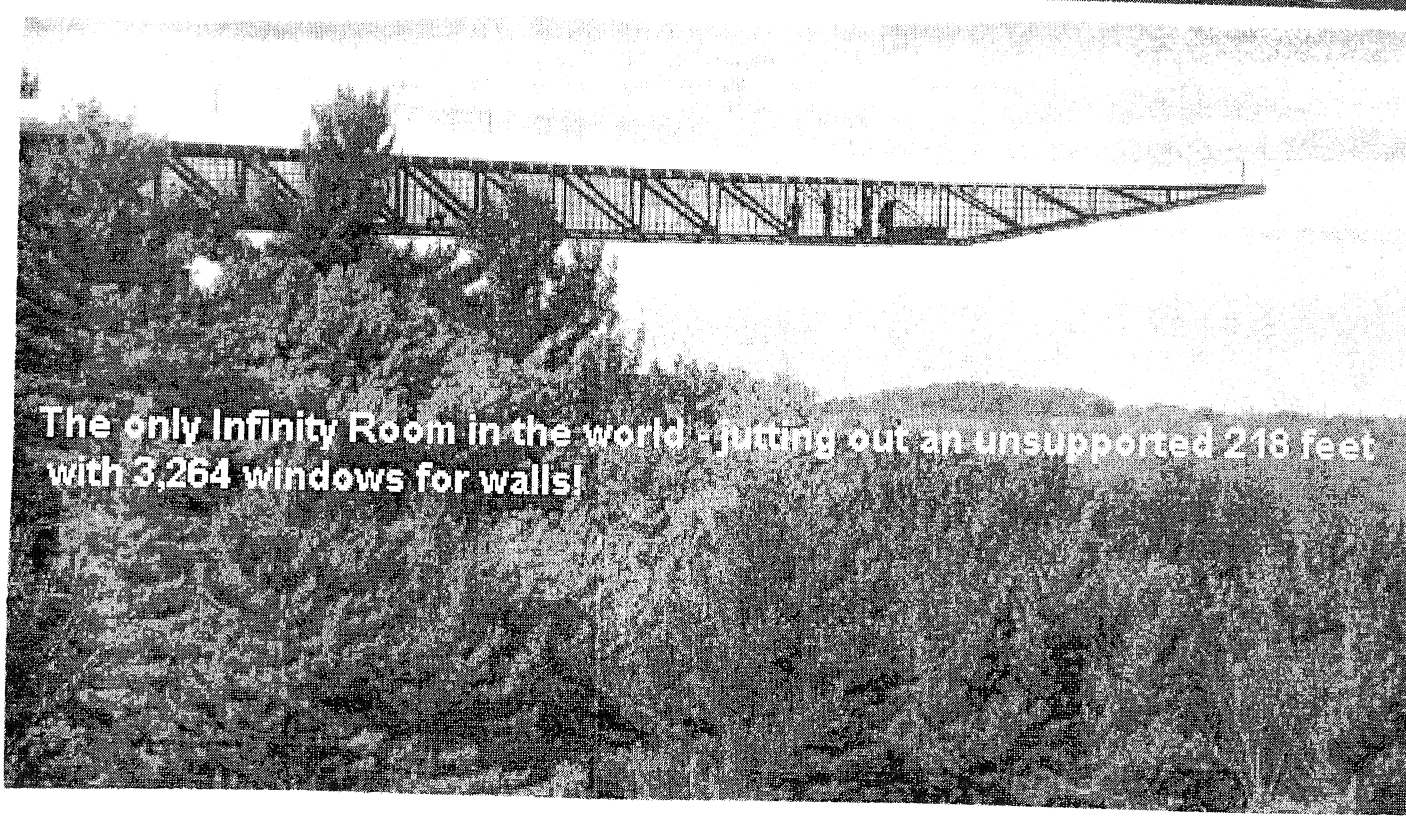
A cantilever is really a large bracket, held rigidly at one end. Here are pictures of some examples.





When we hold something, we know from experience that it is harder to hold it out at arms length than closer to the body. We might refer to this in terms of leverage. In the picture we see a leaning tree that has become unable to support itself, because its position is unstable. The more it leans, the greater the ability of its weight to turn it further, and of course, unlike any bridge, it is still grower, making the effects even worse. The solution was one that bridge designers use whenever possible, make the span or the cantilever arm as short as possible, here achieved with two props. Although bridges do not grow, the traffic on them can certainly do so, in some cases necessitating expensive strengthening or even duplication of the bridge. Strengthening can tax the ingenuity of engineers even more than the original design, especially if the bridge is a very old one which they wish to preserve with as little disfigurement as possible.





The only Infinity Room in the world - jutting out an unsupported 218 feet with 3,264 windows for walls!

Name:_______________

What Makes a Strong Structure? What Weakens a Structure?
What Forces Affect Structures?

In order to build a successful structure you need to know what forces will affect that structure. You will also need to know what materials are best suited for specific jobs. In this activity you will research and take notes on forces, loads, materials, and shapes that affect bridges.

Log on to http://www.pbs.org/wgbh/buildingbig/ website and click on the bridges link. Check out the Website and Answer the following questions that go with this worksheet. Turn in when completed. Worth 15 pts.

Forces, Loads, Materials, Shapes Lab

Check out how different forces, loads, materials and shapes affect bridges. Make sure that you take notes and understand how each thing affects bridges.

Forces Lab

Compression:

Tension:

Bending:

Shear:

Torsion:

Loads Lab

Weight of Structure:

Weight of Objects:

Soft Soil:

Temperature:

Earthquake:

Wind:

Vibration:

Material Lab

Wood:

Plastic:

Aluminum:

Brick:

Concrete:

Reinforced Concrete:

Cast Iron:

Steel:

Shapes Lab:

Rectangle:

Arch:

Triangle:

Name:________________

Design & Engineering-Cantilever Structure

Architect/Civil Engineer

Please answer these questions honestly and completely. Your comments will help in the planning of other independent projects.

1. What did you like about this engineering project?

2. What didn't you like about this engineering project?

3. Any suggestions to make this assignment better?

4. Was this assignment challenging?

5. Did you have to use what you've learned in Design & Engineering to help complete this project? What?

6. What would you do differently if you could do this project again?

7. Who has the best cantilever structure? Why? Which one will hold the most weight?

8. What was the most difficult thing about this project?

Structure Terms Sheet

Using the Building Big Website, the Building Big: Bridges Video or the Internet, write the definitions of the following terms. You will need to identify the terms on the exam.

Arch Bridge -

Beam Bridge -

Bend -

Brace -

Buckle -

Cable -

Cable-Stayed Bridge -

Caisson -

Cantilever -

Civil Engineer -

Column -

Compression -

Deform -

Engineering -

Force -

Load -

Pressure -

Rigid -

Shear -

Span -

Stable -

Suspension Bridge -

Tension -

Torsion -

Truss -

Unstable -

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Truss -

Unstable -

Name:_______________

Structures Exam-52pts.

Fill in the blank with the appropriate term that goes with the definition.

1. ________
a curved structure that converts the downward force of its own weight, and of any weight pressing down on top of it, into an outward force along its sides and base

2. ________
any action that tends to maintain or alter the position of a structure

3. ________
a profession in which a knowledge of math and natural science is applied to develop ways to utilize the materials and forces of nature for the benefit of all human beings

4. ________
a simple type of bridge, composed of horizontal beams supported by vertical posts

5. ________
characteristic of a structure that collapses or deforms under a realistic load

6. ________
a bridge in which the roadway deck is suspended from cables that pass over two towers; the cables are anchored in housings at either end of the bridge

7. ________
a force applied or distributed over an area

8. ________
weight distribution throughout a structure; **loads** caused by wind, earthquakes, and gravity, for example, affect how weight is distributed throughout a structure

9. ________
a watertight, dry chamber in which people can work underwater

10. ________
a vertical, structural element, strong in compression

11. ________
(n.) a structural support; **(v.)** to strengthen and stiffen a structure to resist loads

12. ________
a bridge in which the roadway deck is suspended from cables anchored to one or more towers

13. ________
(v.) to curve; bending occurs when a straight material becomes curved; one side squeezes together in compression, and the other side stretches apart in

14. ________
to change shape

15. ________
a pressing force that squeezes a material together

16. ________
an engineer who plans, designs, and supervises the construction of facilities essential to modern life

17. ________
to bend under compression

18. ________
a structural element formed from steel wire bound in strands; the suspending element in a bridge; the supporting element in some dome roofs

19. ________
a projecting structure supported only at one end, like a shelf bracket or a diving board

20. ________
a rigid frame composed of short, straight pieces joined to form a series of triangles or other stable shapes

21. ________
(adj.) ability to resist deformation when subjected to a load; **rigidity (n.)** the measure of a structure's ability not to change shape when subjected to a load

22. ________
(adj.) ability to resist collapse and deformation; **stability (n.)** characteristic of a structure that is able to carry a realistic load without collapsing or deforming significantly

23. ________
a force that causes parts of a material to slide past one another in opposite directions

24. ________
an action that twists a material

25. ________
(n.) the distance a bridge extends between two supports; **(v.)** to traverse a specific distance

26. ________
a stretching force that pulls on a material