2009 – 2010 Elevated Bridge

November, 2009

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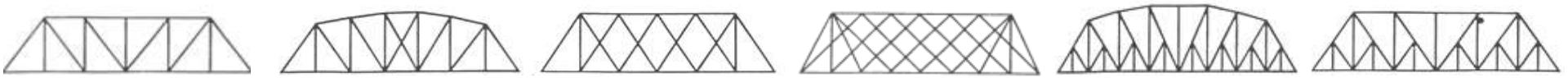
: http://wisconsinso.org/divc/Events/ElevatedBridge2009.html

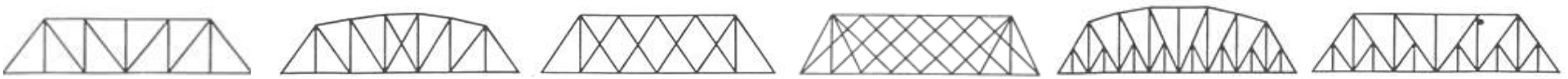


Elevated Bridge Objective

- Design and build the most efficient bridge to hold a single point mass.
- Bridge Efficiency = mass held by bridge / mass of bridge.

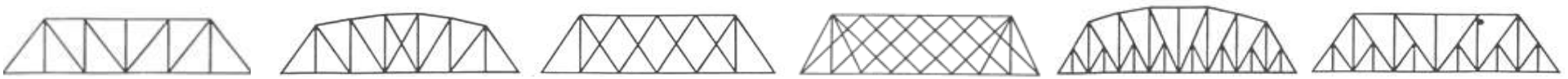
Key Changes from 2009

- Wood size no longer limited…the ¼" x ¼" rule dropped!
- Size of standard minimum clearance has been increased. Greater challenge and fun! ☺



Project Log

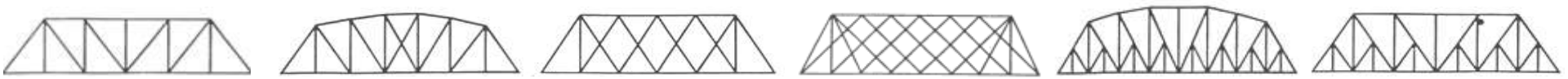
- While it is not required, I encourage the development of a project log.
- Reinforces use of the scientific process or method
- It is good documentation for this year's team and next year's team!
- Practice for workplace research (future career?).
- Include:
  - Bridge research
  - Design hypothesis
  - Bridge design and calculations
  - Testing notes, photos and sketches
  - Observations and conclusions
- Web references
  - http://www.sciencebuddies.org/science-fair-projects/printable_project_logbook.pdf
  - http://schoolscience.rice.edu/duker/thompson/log.html



Key Construction Rules for 2010

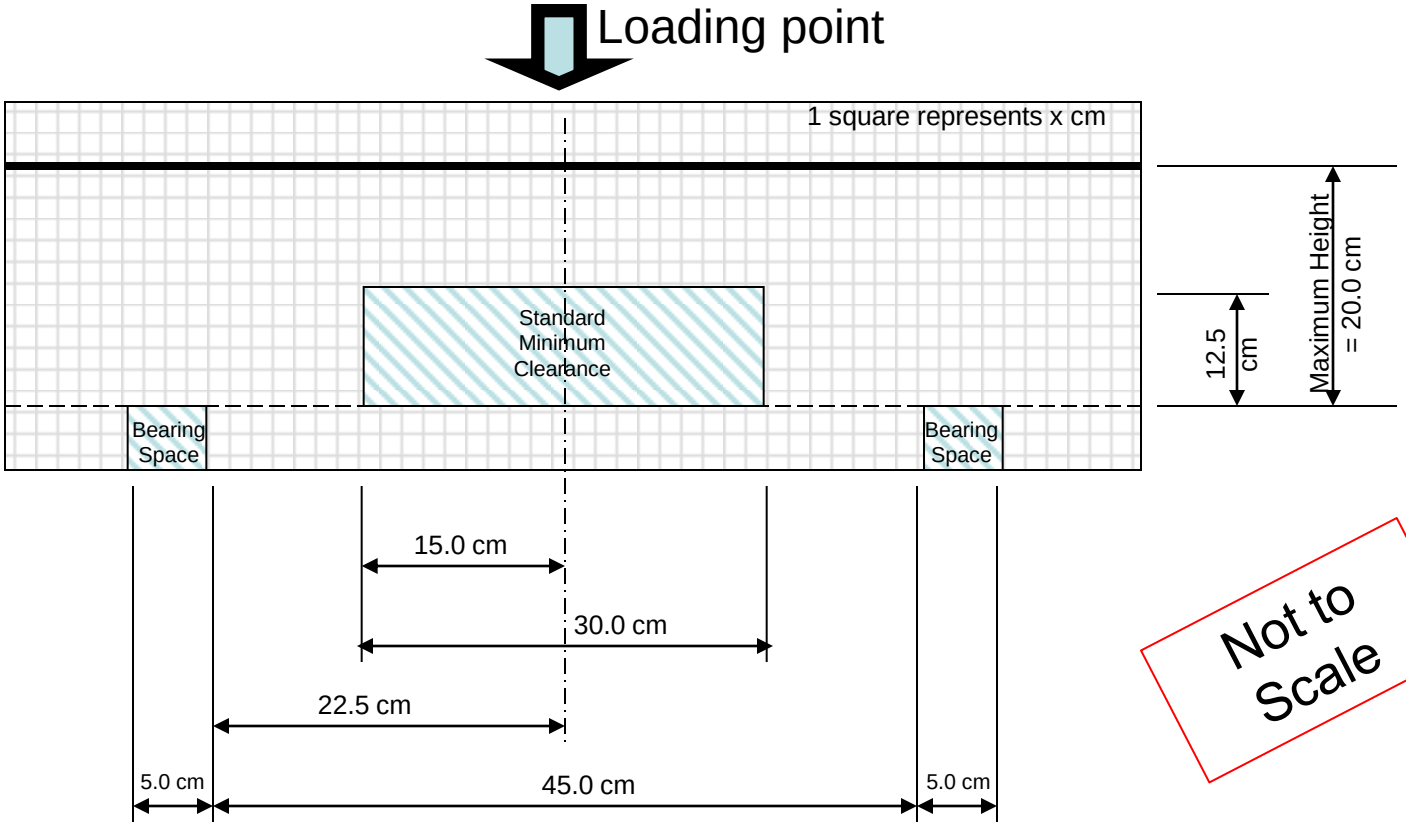
Single structure, no separate or detachable pieces	3.h
Constructed of wood, bonded with glue only	3.i
Particle board, wood products, bamboo, paper or commercially laminated wood may NOT be used.	3.i
Unlimited lamination by the student is allowed	3.k
Maximum height of bridge will be 20.0 cm	3.d
Bridge has a clear span of 35 cm (div B) or 45 cm (div C) and only touches test base in bearing zone	3.a
Bridge does not extend below the top of the test base, no braces against edges of the test base	3.b
Bridge clears standard minimum clearance block 15.0 cm x 15.0 cm (div B) or 30.0 cm x 12.5 cm (div C)	3.c
Bridge supports loading block at center of bridge and above standard minimum clearance with clearance for chain	3.e, 5.e

In the 2009 Wisconsin state competition, 11 of the 59 of the Elevated Bridges did not meet the building rules!



Bridge Design Template

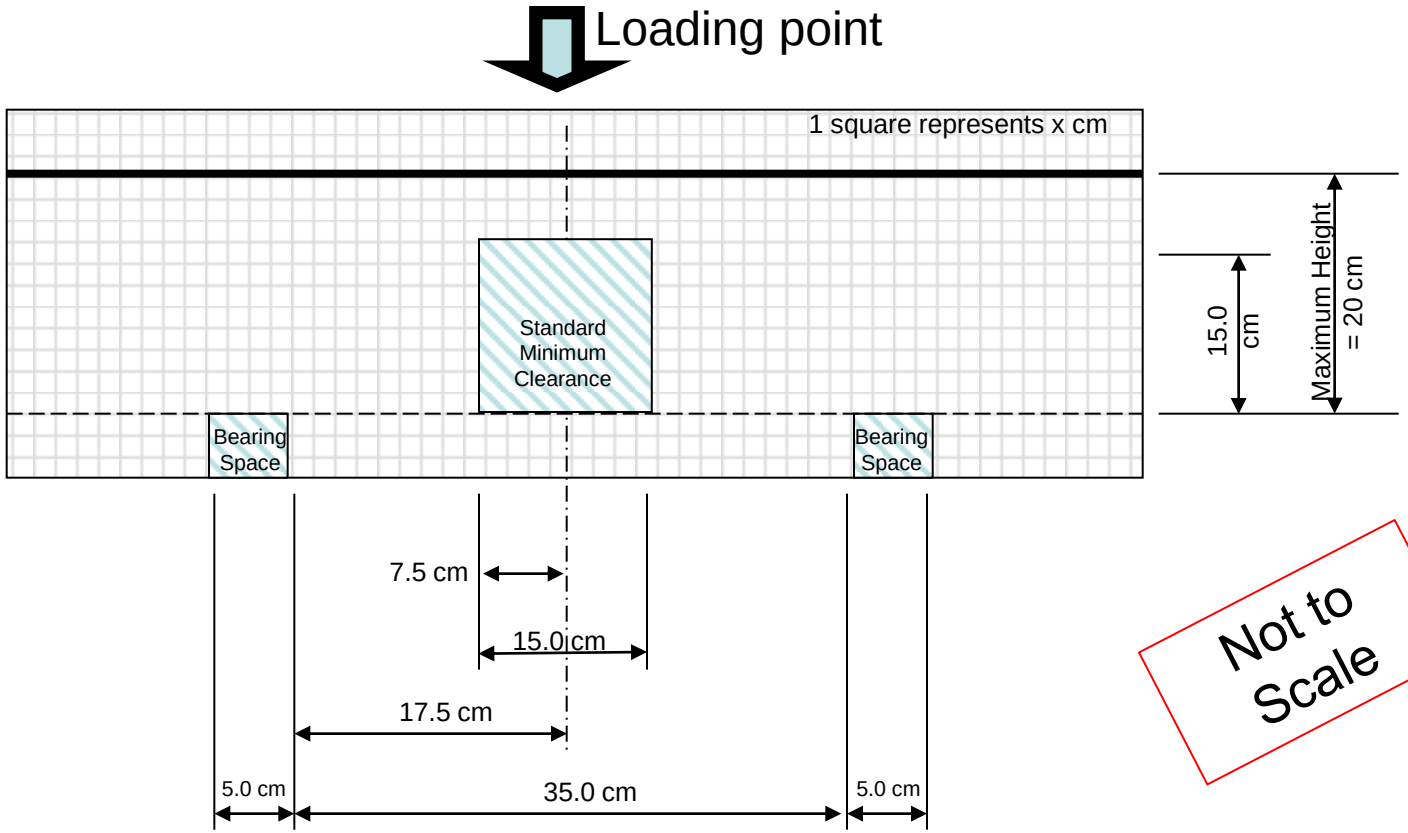
Division C



Not to Scale

Bridge Design Template

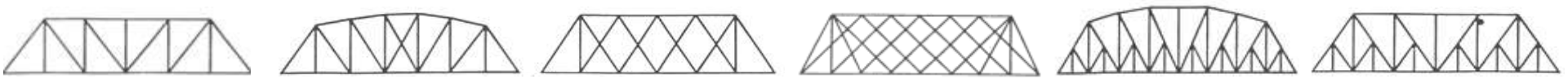
Division B



Not to Scale

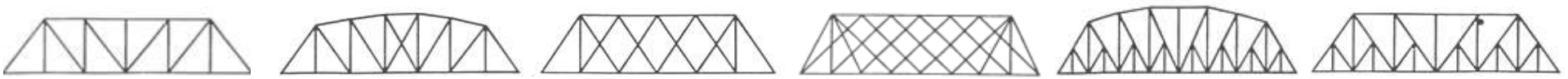
What's not in the rules!

- Test base does not provide lateral resistance!
- Bottom chord of bridge may be interrupted
- Bridge may slide during loading
- Bridge may sag when loaded (but not touch the base)
- No maximum width of the bridge, but needs to fit on test stand

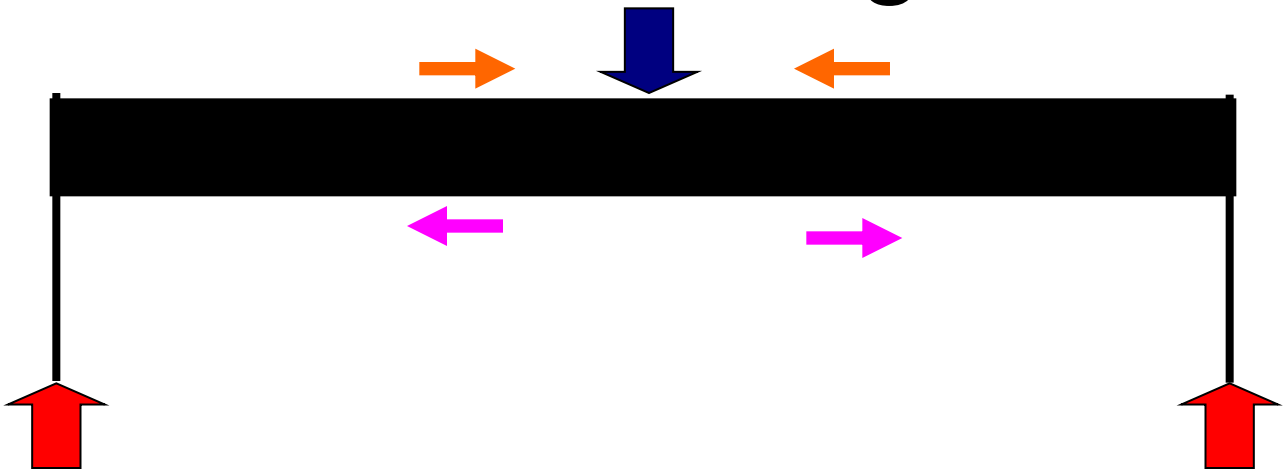


Bridge Considerations

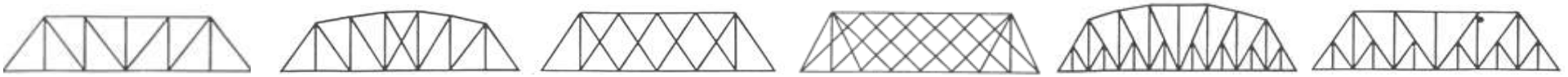
- Bridge Types
- Wood
- Glue
- Building Tips
- Testing Day



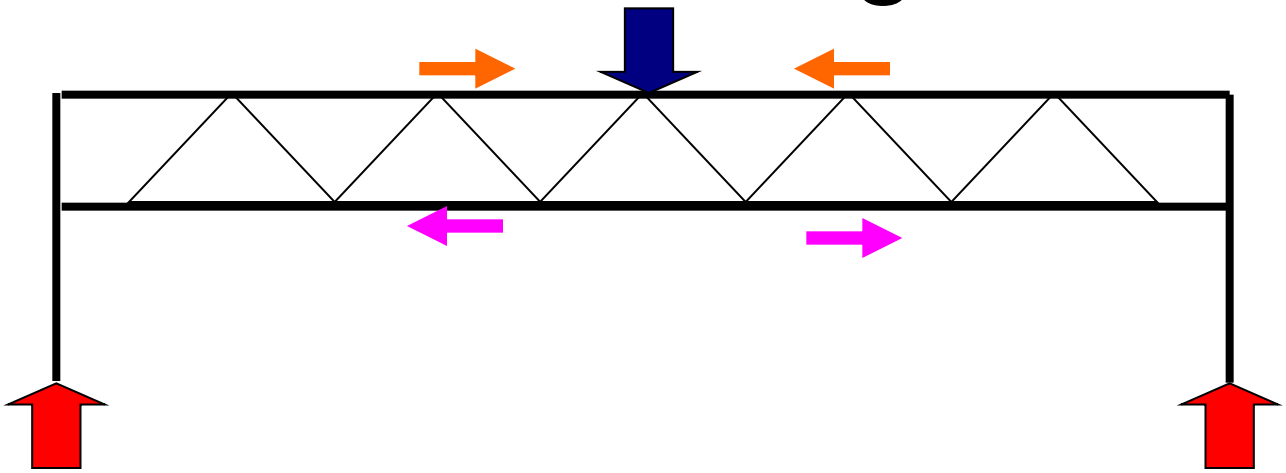
Beam Bridge



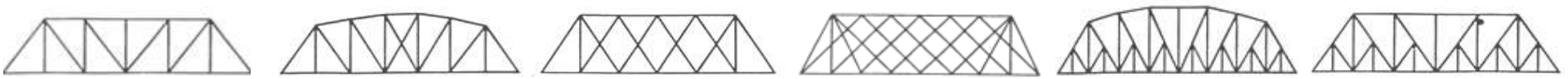
- Direct descendant of the log bridge. Same as many interstate overpasses
- In structural terms, the simplest of the many bridge types
- May be heavier than other bridge designs
- If designed and built well, no horizontal resultant forces

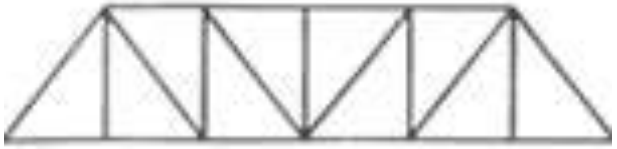


Truss Bridge

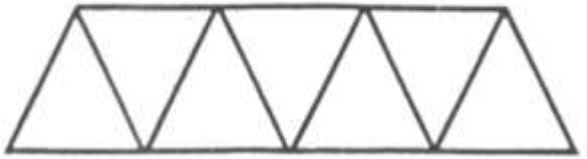


- Composed of connected elements (typically straight)
- Oldest types of modern bridges.
- Efficient use of materials
- If designed and built well, no horizontal resultant forces

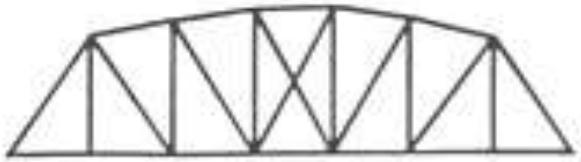




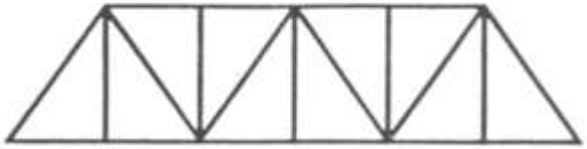
Pratt



Warren

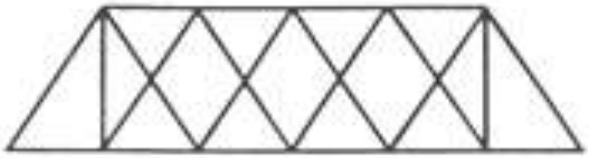


Curved Chord Pratt



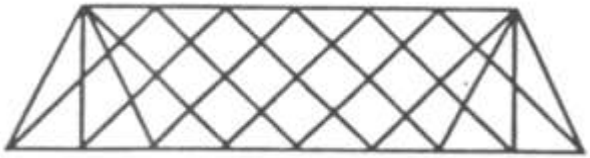
Warren with vertical supports

Baltimore

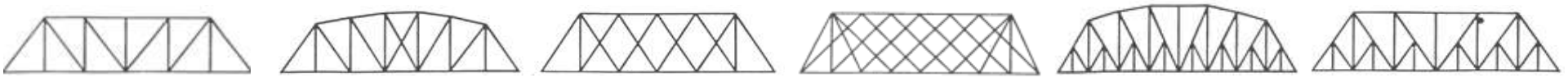


Quadrangular Warren

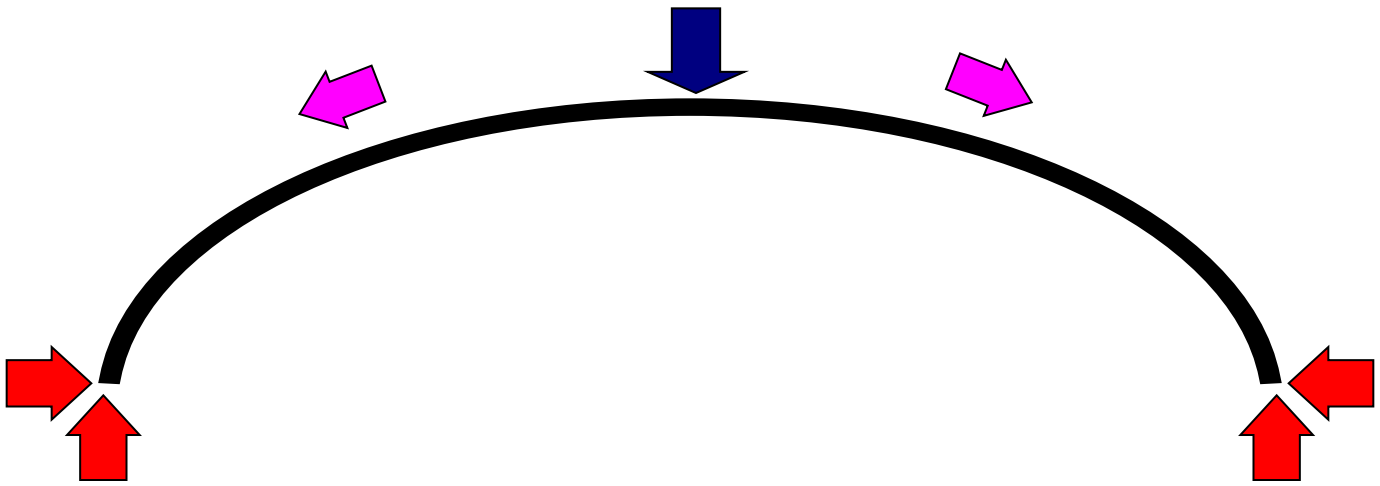
Pennsylvania



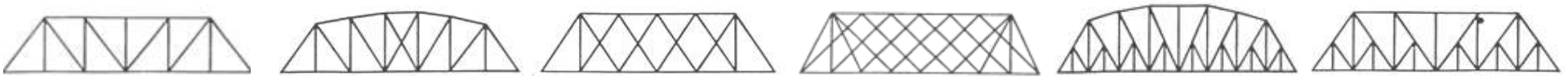
Lattice



Arch



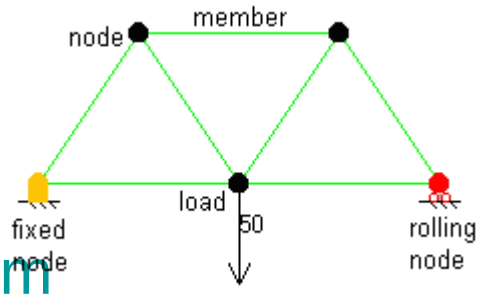
- Efficient use of materials
- Can have horizontal resultant forces
- Need to stablilze



Web Design Support

Have students check out the Building Big web site at:

http://www.buildingbig.com



Design your own bridge at:

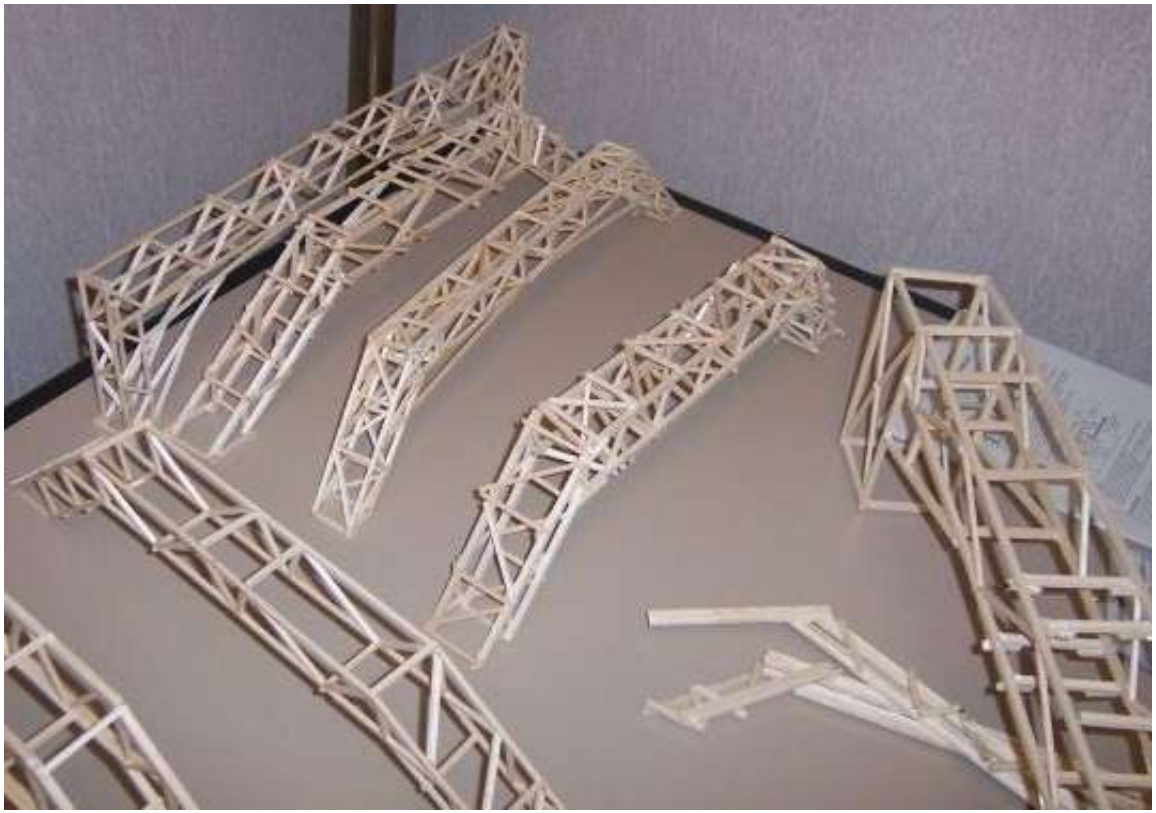
http://www.jhu.edu/~virtlab/bridge/bridge.htm

http://www.jhu.edu/~virtlab/bridge/truss.htm

And have them try the following:

http://www.pbs.org/wgbh/buildingbig/lab/forces.html

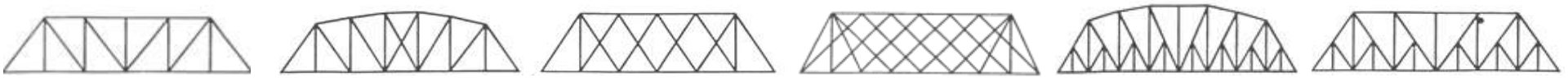
Photos from a 2008 Summer Workshop



Photos the 2009 State Meet

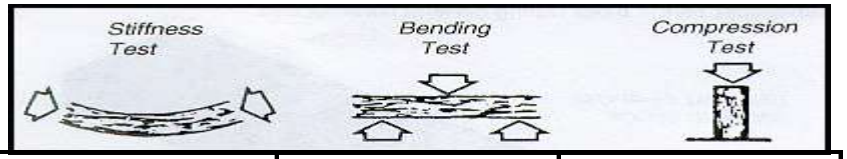
See photos from the 2009 Wisconsin State meet held in May 2009 at:

C bridges pics and videos (state)
http://www.flickr.com/photos/tennocram/sets/72157617955725202/
and slideshow view
http://www.flickr.com/photos/tennocram/sets/72157617955725202/show/



Wood

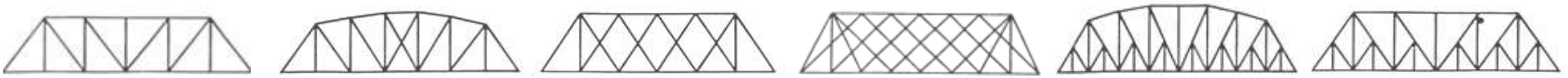
Balsa, strongest wood, pound for pound!



Species	*Density (Lbs / cu Ft)*	*Stiffness*	*Bending*	*Compression*
Balsa	8	72	70	75
Balsa	10	100	100	100
Balsa	14	156	161	149
Basswood	26	261	288	288
Pine, Spruce	28	230	260	289
Yellow Pine	28	222	277	288
Balsam Fir	30	241	291	341
Black Walnut	37	301	506	512
Oak	48	295	430	366
Hickory	50	379	638	514

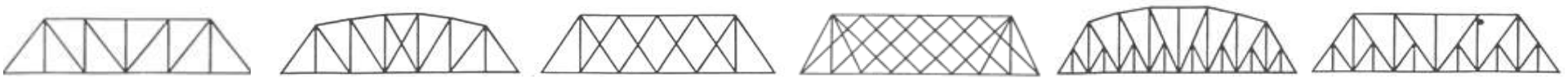
NOTE ABOUT CHART: The strength of balsa varies in direct relation to its density or weight - the heavier the wood the stronger it is. The above chart was designed with 10 lb./cu. ft. balsa as the median. In other words, balsa at IO lbs./cu. ft. has been tested given a value of 100. The other woods were then tested in the same way and given a figure that is numerically in proportion. By comparing the relative strength figures in the chart, it will be seen that balsa is as strong or stronger, pound for pound, than most of the species shown.

From: **SIG MANUFACTURING'S ITERESTING FACTS ABOUT BALSA WOOD** http://www.go-cl.se/balsa.html



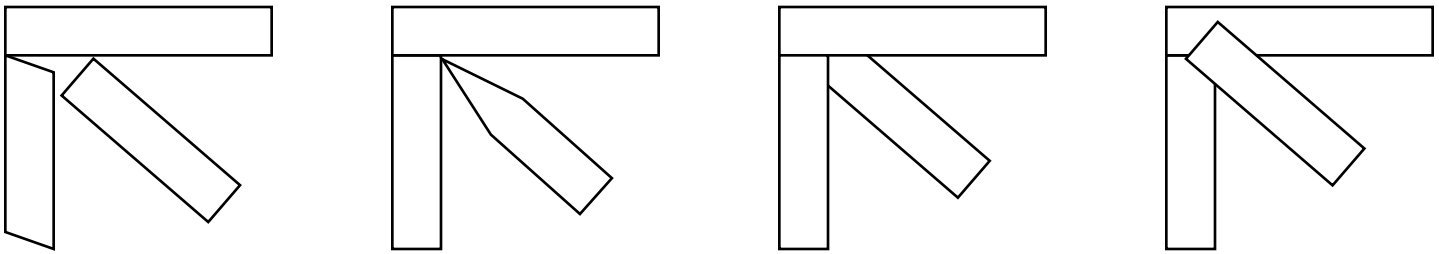
Wood

- Check carefully for grain defects, cuts, chips or other damage.
- Mass like size woods for consistency… especially balsa.



Joints

- Good craftsmanship is critical!
- Good joints = joints with no gaps
- Slight roughness glues better than super smooth

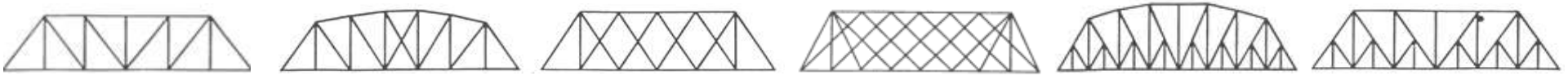


Poor Joints

Good Joints

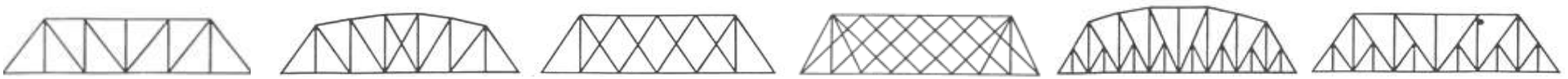
Well cut and fit joints

Flat joints, easy to make



Glue

- Read the Material Safety Data Sheet (MSDS)…Safety First
- Glue Choice…not critical from a strength point of view. Wood shear parallel to grain is less than 2,000 psi for common woods, most glues above 2,000 psi.
- Use sparingly…it is heavy
- Shelf life is typically a year or two...check date code



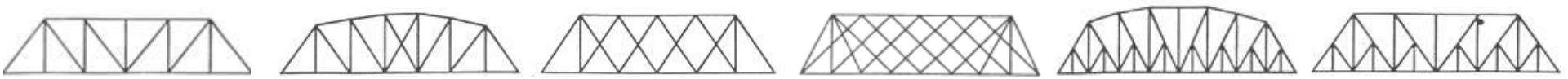
Glue

GLUE OPTIONS	Polyvinyl Acetate	Polyurethane	Epoxy	Cyanoacrylate
Shear Strength (psi)	3,600	3,500	2,000	3,000
Open Time / Clamp Time (Minutes)	10 / 60	10 / 120	15 / 45	1 / 1
Notes	Water based, will not fill gaps	Needs moisture to cure	Does not shrink	Will not fill gaps
Health / Safety		Wear PPE	Wear PPE	Wear PPE
Cost ($/oz) (more stars, higher cost)	★	★★	★★★★	★★★★ ★★★★
Brands	Titebond Original, Elmer's Carpenter's, Tacky Formula Modeling Glue	Gorilla, Elmer's Probond, Titebond, ExcelOne	System Three T-88, Industrial G-1	Gorilla Super, Krazy glue, Super 'T', Permabond

PPE = Personal Protective Equipment

Gluing

- Clean, dry, dust free surfaces!
- Maximize surface area
- “wet” both surfaces with glue and then assemble.
- Normally need to “clamp joint” for best bond and air elimination
- Glue at 65° F or higher

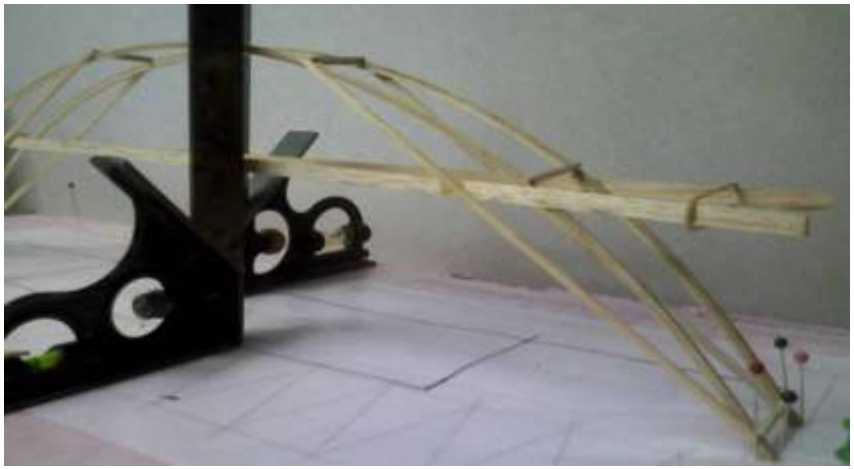


Assembly Tips

- Draw plan to scale
- Place plan on Styrofoam
- Cover with wax paper
- Build: pin in place & glue
- Weigh down or “clamp”

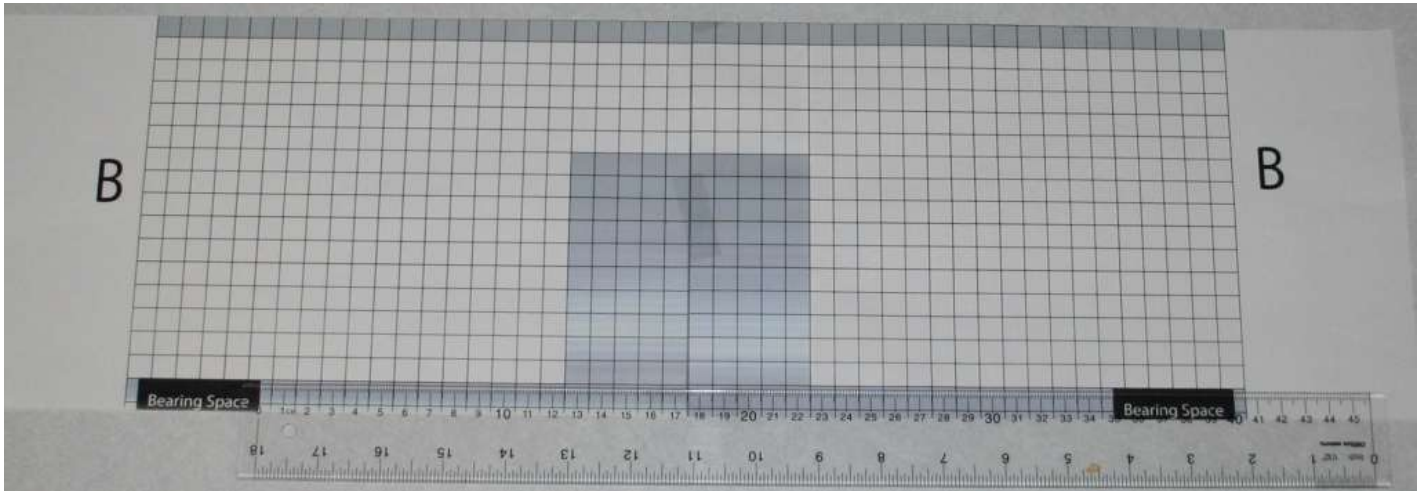
Assembly Tips

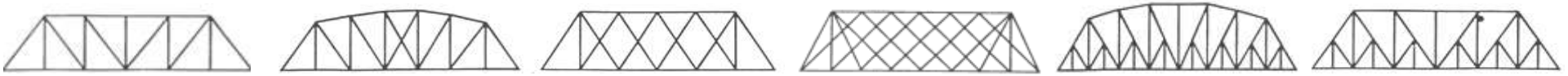
- Based on your design, align sides so they are straight, square and parallel.
- Be sure to install cross bracing between sides to prevent sideways sagging



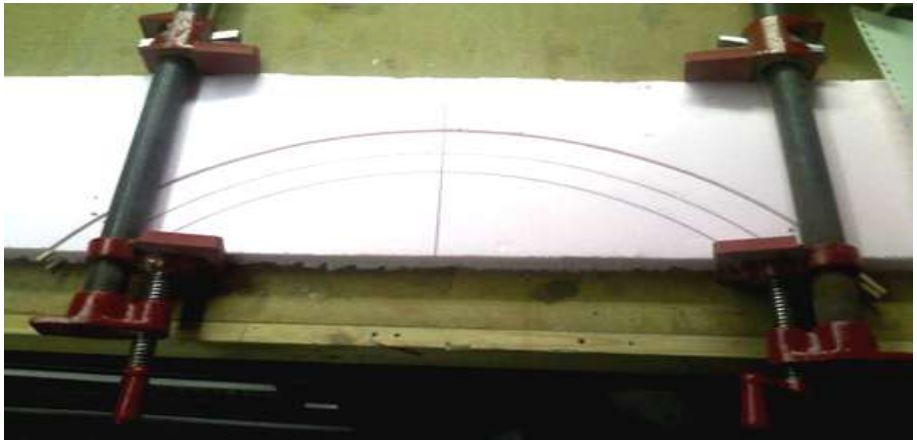
Design Templates

- Print appropriate template set for Division B or Division C. Each template has 2 sheets
- Print on 11 x 17 or 8-1/2 x 14.
- In the print options, uncheck the “scale to page” option
- Use straight edge to align sections and assure distance between bearing zones is 35.0 cm (division B) or 45.0 cm (division C).
- Each square should measure 1.0 cm x 1.0 cm.
- Tape, trim and design.





Bending Wood



- Design shape, build form. Styrofoam is good for Balsa wood.
- Steam or soak wood in hot water until soft (or use microwave method)
- Use diluted glue if laminating.
- Clamp until dry
- Web reference: http://www.allwoodwork.com/article/woodwork/methods_of_bending_wood.htm

Storage and Transportation

• Cardboard box with Styrofoam packing peanuts works great!

Foam lined box used for a boomilever

The ultimate in transport boxes, wooden box for a tower!!

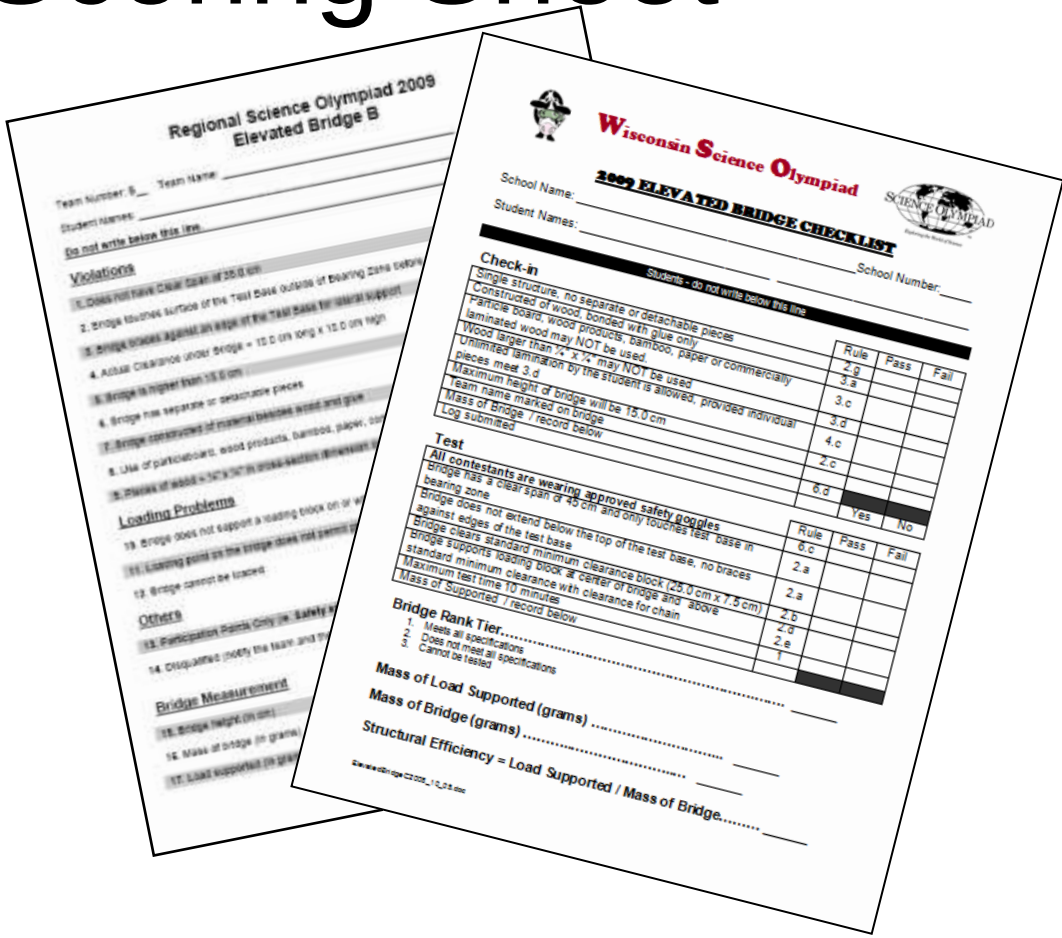
Test Day!

- Finally!
- No impound, so bring bridge in a box and store safely.
- Place Name on bridge (not a rule, but judges like it)
- Register for a test time
- Check-in 10 minutes before test time and have bridge inspected
- Test!

Check-in Scoring Sheet

The scoring sheet is a summary of the rules. It does not replace the rules!

However, you should review your design with this sheet!

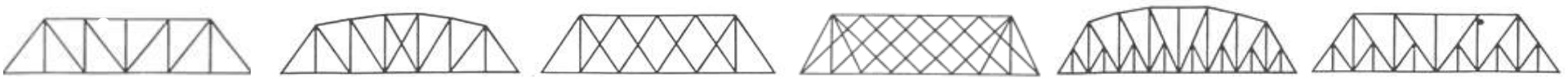


Web links:

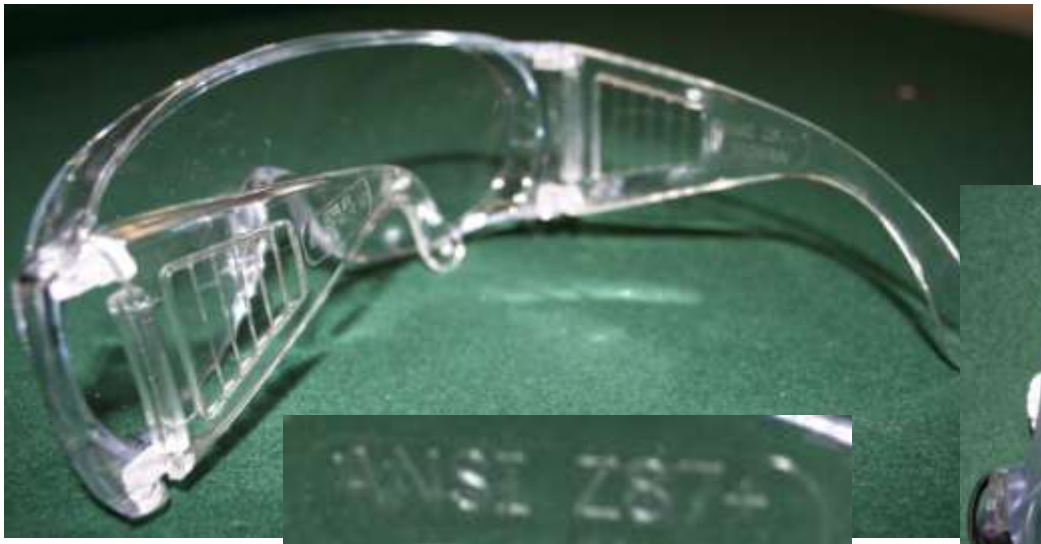
Wisconsin SO: http://wisconsinso.org/divc/Events/ElevatedBridge2009.html
National SO: http://soinc.org/elevated_bridge_c

Eye Protection

- Contestants are responsible for providing “safety spectacles with side shields” (rule 1, 2.b)
- Eye protection must be manufactured to meet the American National Standards Institute standard. The current standard is ANSI Z87.1-2003. Approved protective eyewear can be identified by the mark "Z87"
- High impact particle protection may be used and is designated by “Z87+”
- **Note:** Prescription glasses must bear the "Z87" mark to be used.
- Web link: http://soinc.org/eye_protection

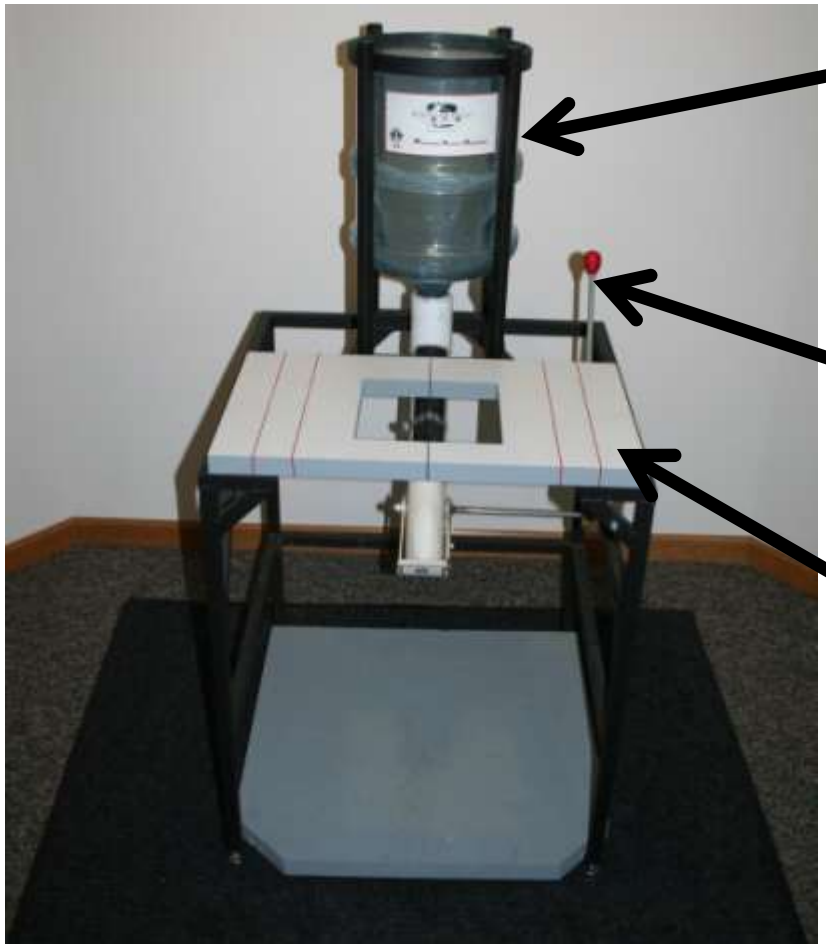


Eye Protection



Test Stand

- Sand or similar will be used for the load.
- 15 kg of sand will be laded into the sand hopper before the test.

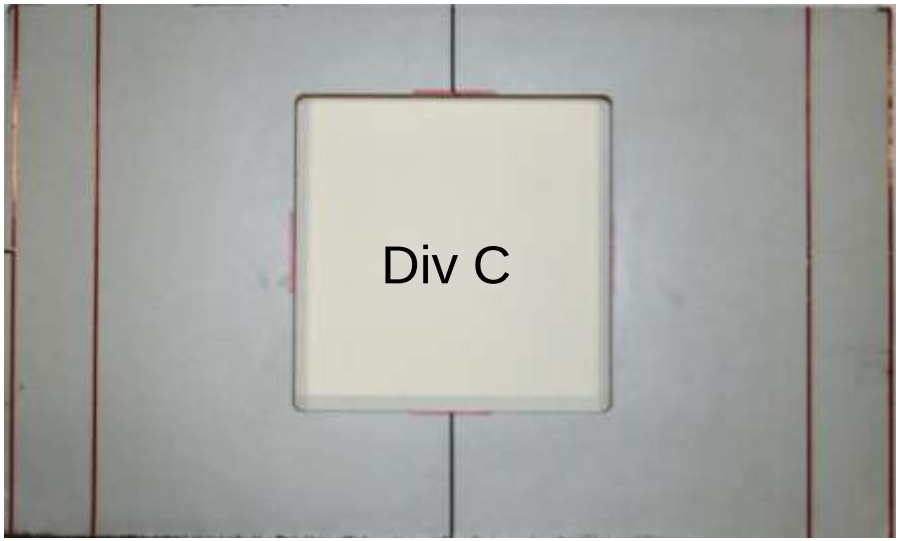


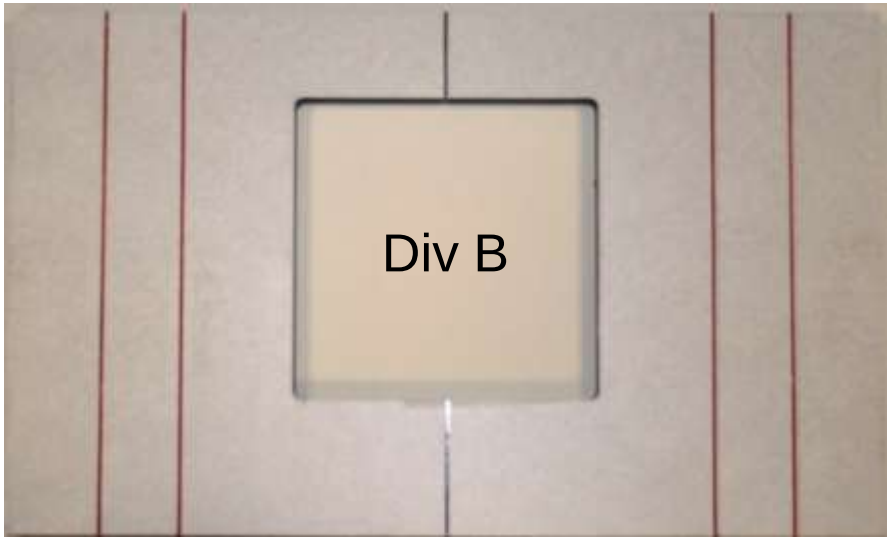
Test Base

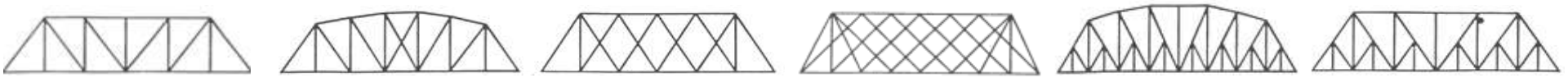
5 parallel lines:

- 1 - Center Line
- 4 -Lines outlining Bearing Zones, lines are out of bounds
- Minimum Size: 55 cm x 32 cm
- Opening 20 cm x 20 cm

Smooth, hard surface (such as metal or laminate)

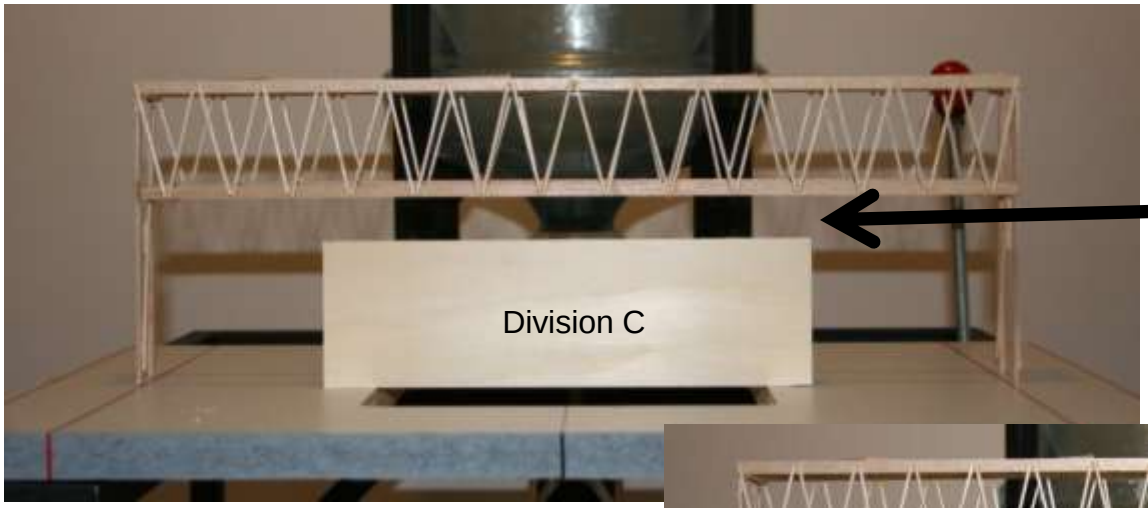






Clearance Blocks

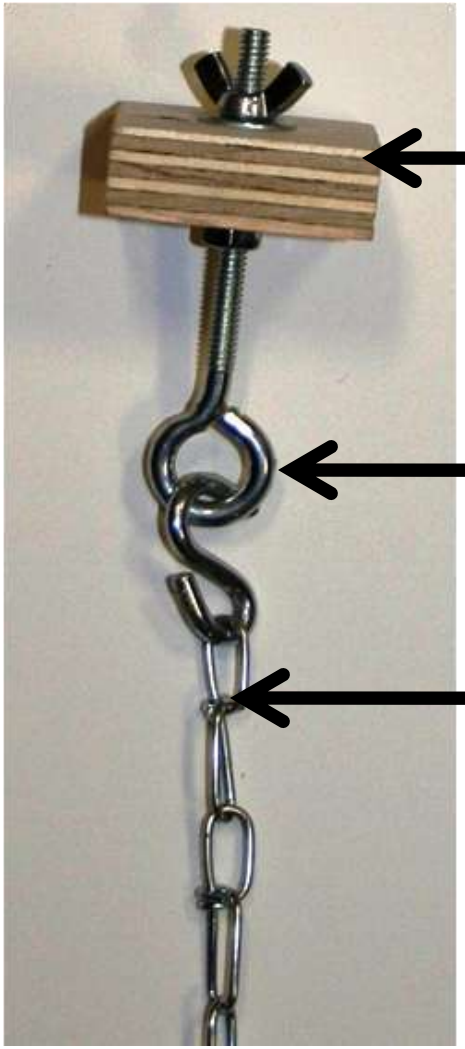
Used to verify standard minimum clearance under bridge per rule 3.c



Pass

Fail

Loading Block



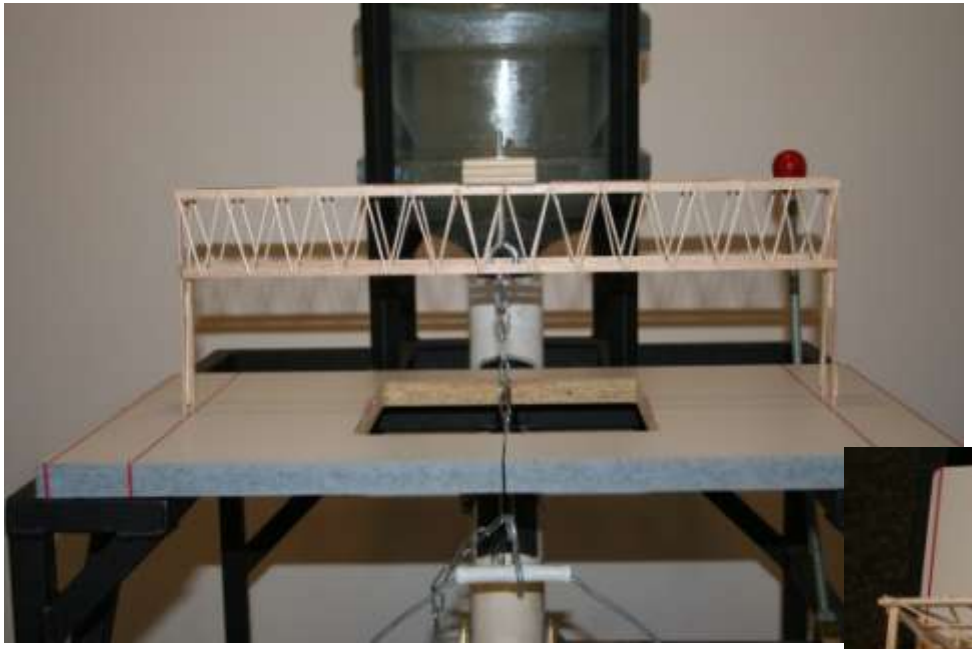
- Block
  - 5.0 cm x 5.0 cm
  - Made of any material (typically wood, plywood, steel or aluminum)
- Bolt
  - ¼ inch threaded eye bolt with washers and wing nut
- Chain
  - Standard wire chain, 75# test
  - Open “s” hook for attachment

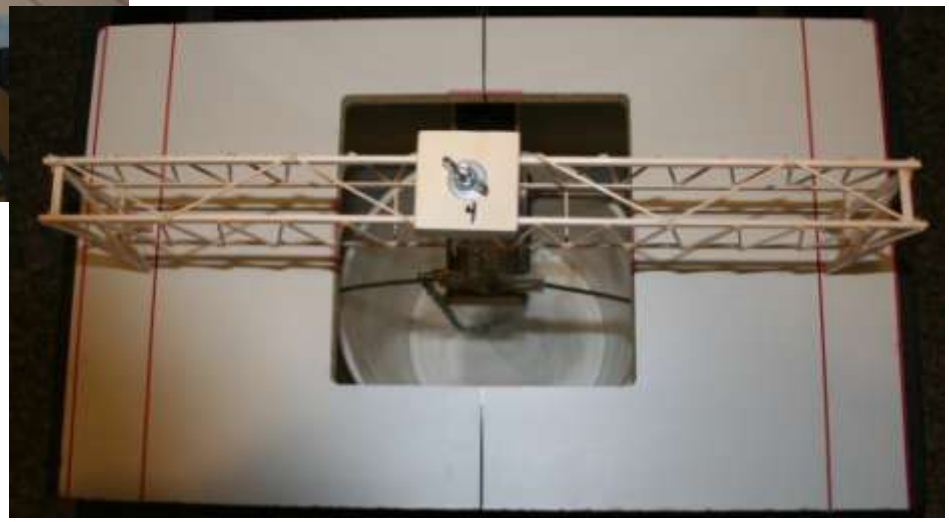
Testing

Contestants will:

- Wear eye protection
- Set bridge on stand
- Set loading block and attach bucket
- Load the sand until failure, until15 kg. loaded or until 10 minutes has expired.

Testing

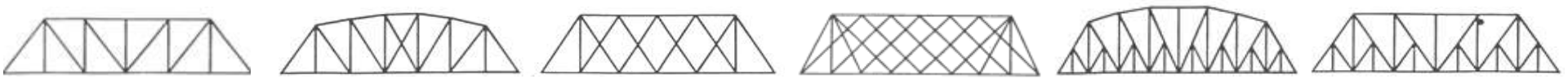




Failure is when:

- Bridge breaks
- Bridge deflects so that the bridge or loading block touches or extends below the top surface of the test base within the clear span.
- The bucket rests on the floor

(Rule 5.h)

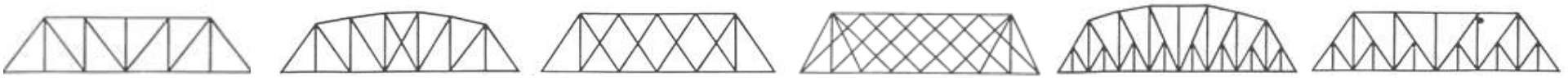


Ranking of Bridges

- Summary of section 6 of rules
- Tier 1 – meets all building rules
  - Ranked ahead of Tier 1 and Tier 2 by Efficiency
  - Event Winner: Tier 1 bridge with highest efficiency

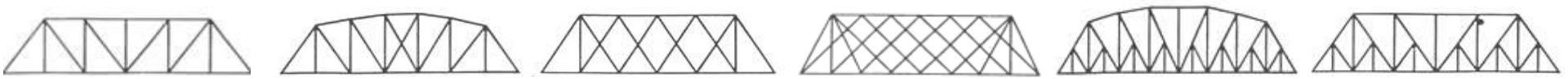
$$\text{Efficiency} = \frac{\text{Load Supported (g)}}{\text{Mass of Bridge (g)}}$$

Note - Load Supported – for scoring purposes the load scored cannot exceed 15,000 grams



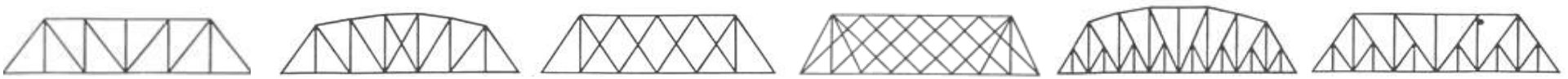
Ranking of Bridges

- Tier 2 – one or more rules not met
  - Ranked after Tier 1
  - Ranked by Structural Efficiency
- Tier 3 – would not support load
  - Ranked after Tier 1 and Tier 2
  - Ranked by lowest to highest mass



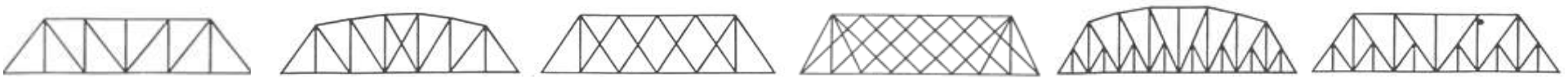
Top Issues in 2008 - 2009

- Bridge not built to specifications
  - Clear span too short
  - Height, taller than allowed
  - Standard Clearance did not fit under bridge
- Painted or coated wood
- Loading block will not fit on structure
- Chain does not pass thru structure
- Structure is broken or damaged in transporting to meet
- Not built straight…causing unbalanced forces
- Bridge did not have enough cross bracing



Suggestions

- Read the rules
- Re-read the rules
- Do some research; books, internet…or just look at some bridges.
- Talk with your Physics teacher! Talk with your TechEd teacher! They will have ideas!
- Video all tests! Review in slow motion.
- Build, test, break, review and document in log. Build, test, break, review and document in log. Build, test, break, review and document in log. Target 1 cycle per week!
- HAVE FUN!!!



Suggestions

- Easy Cutter for safe cutting of wood. May be helpful for some students.