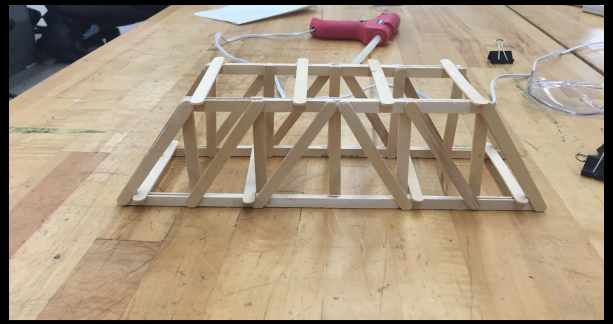
Design Project #1

Replacement of Vehicle Bridge over Spring Creek

Centre County, PA

Introduction to Engineering Design

EDGSN 100 Section 002



You Can't Sit With Us

Design Team 6

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STATEMENT OF PROBLEM

Flooding has caused the previous bridge located over Spring Creek along Puddintown Road to become structurally unstable, and to be destroyed. Since the bridge is heavily traveled and connects the residence and emergency vehicles to the Medical Center it has become a vital lifeline. Without a bridge there is a 10 mile detour that cuts off College Township from the rest of the region.

Photo 4A. Examples of stormwater input into Millbrook Marsh - Road runoff from E. College Ave. and Puddintown Road at the Thompson Run bridge, east side.

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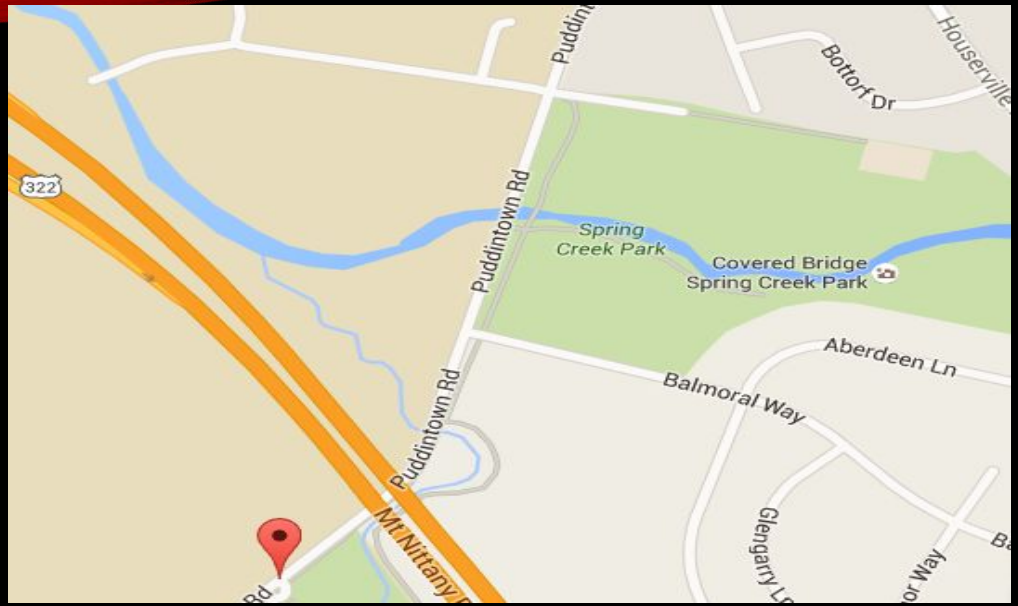

OBJECTIVE

- To create a well designed vehicle bridge that will expand over Spring Creek, and will be both structurally sound and cost efficient.

DESIGN CRITERIA

The bridge design must be:

- Structurally Efficient
- Economically Efficient
- Howe/Warren Truss
- Have a max of 60 popsicle sticks
- Contain 8 floor beams and struts.

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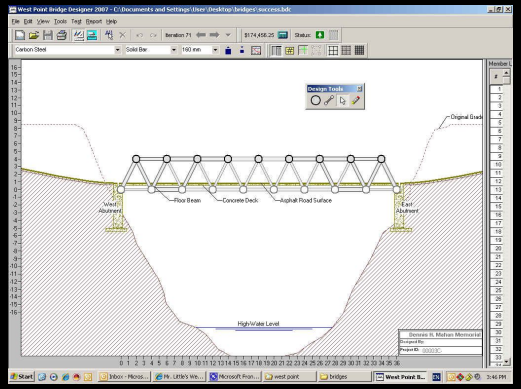
TECHNICAL APPROACH PHASE 1: ECONOMIC EFFICIENCY

To find the most economically efficient bridge we built our own models in the Bridge Designer 2.0 software. The software then lists the costs of each individual member to effectively show total price, and where we can improve our cost efficiency.



How we looked to lower costs:

- Used correct material type depending on whether member was T or C
- Used uniform members where possible
- Shorten length of individual members
- Made all strains of T and C as close to 1 as possible

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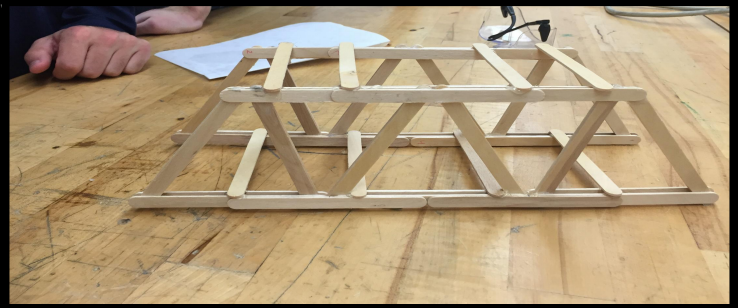
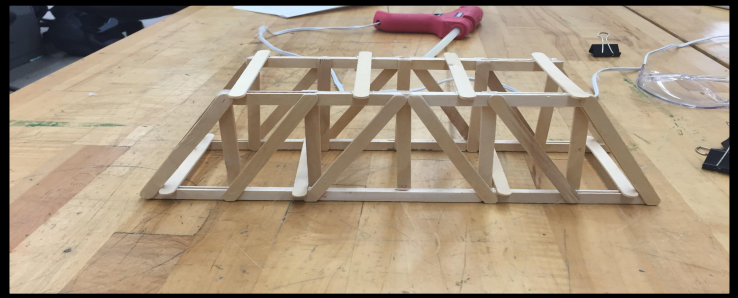
TECHNICAL APPROACH PHASE 2: STRUCTURAL EFFICIENCY

To find out which of the two types of trusses was most structurally efficient:

- Two trusses were built with popsicle sticks from a total of 120 sticks. (Each had 8 floor beams/struts)
- The trusses were load tested to their breaking points.
- Structural Efficiency was then calculated from the bridges' weights and load test results.

Warren Truss





Howe Truss

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RESULTS PHASE 1: ECONOMIC EFFICIENCY

Economic Efficiency (Howe Truss)			
Type of Cost	Item	Cost Calculation	Cost
Material Cost (M)	Carbon Steel Solid Bar	(15483.4 kg) x ($4.30 per kg) x (2 Trusses) =	$133,157.58
	Carbon Steel Hollow Tube	(505.9 kg) x ($6.30 per kg) x (2 Trusses) =	$6,374.55
	Quenched & Tempered Steel Solid Bar	(2293.8 kg) x ($6.00 per kg) x (2 Trusses) =	$27,525.60
	Quenched & Tempered Steel Hollow Tube	(325.6 kg) x ($7.70 per kg) x (2 Trusses) =	$5,013.55
Connection Cost (C)		(22 Joints) x (500.0 per joint) x (2 Trusses) =	$22,000.00
Product Cost (P)	2 - 75x75 mm Carbon Steel Bar	(%s per Product) =	$1,000.00
	8 - 80x80 mm Carbon Steel Bar	(%s per Product) =	$1,000.00
	1 - 80x80x4 mm Carbon Steel Tube	(%s per Product) =	$1,000.00
	4 - 80x80 mm Quenched & Tempered Steel Bar	(%s per Product) =	$1,000.00
	14 - 140x140 mm Carbon Steel Bar	(%s per Product) =	$1,000.00
	4 - 140x140x7 mm Carbon Steel Tube	(%s per Product) =	$1,000.00
	4 - 150x150 mm Carbon Steel Bar	(%s per Product) =	$1,000.00
	2 - 160x160 mm Carbon Steel Bar	(%s per Product) =	$1,000.00
	2 - 160x160 mm Quenched & Tempered Steel Bar	(%s per Product) =	$1,000.00
	2 - 170x170x8 mm Quenched & Tempered Steel Tube	(%s per Product) =	$1,000.00
Site Cost (S)	Deck Cost	(10 4-meter panels) x ($4,700.00 per panel) =	$47,000.00
	Excavation Cost	(19,900 cubic meters) x ($1.00 per cubic meter) =	$19,900.00
	Abutment Cost	(2 standard abutments) x ($5,250.00 per abutment) =	$10,500.00
	Pier Cost	No pier =	$0.00
	Cable Anchorage Cost	No anchorages =	$0.00
Total Cost	M + C + P + S	$172,071.29 + $22,000.00 + $10,000.00 + $77,400.00 =	$281,471.29

Cost Calculations Report

Type of Cost	Item	Cost Calculation	Cost
Material Cost (M)	High-Strength Low-Alloy Steel Solid Bar	(5002.0 kg) x ($5.60 per kg) x (2 Trusses) =	$56,022.78
	High-Strength Low-Alloy Steel Hollow Tube	(6266.6 kg) x ($7.00 per kg) x (2 Trusses) =	$87,732.47
Connection Cost (C)		(21 Joints) x (500.0 per joint) x (2 Trusses) =	$21,000.00
Product Cost (P)	12 - 70x70 mm High-Strength Low-Alloy Steel Bar	($1,000.00 per Product) =	$1,000.00
	8 - 100x100 mm High-Strength Low-Alloy Steel Bar	($1,000.00 per Product) =	$1,000.00
	2 - 120x120x6 mm High-Strength Low-Alloy Steel Tube	($1,000.00 per Product) =	$1,000.00
	8 - 200x200x10 mm High-Strength Low-Alloy Steel Tube	($1,000.00 per Product) =	$1,000.00
	6 - 240x240x12 mm High-Strength Low-Alloy Steel Tube	($1,000.00 per Product) =	$1,000.00
	3 - 280x280x14 mm High-Strength Low-Alloy Steel Tube	($1,000.00 per Product) =	$1,000.00
Site Cost (S)	Deck Cost	(10 4-meter panels) x ($4,700.00 per panel) =	$47,000.00
	Excavation Cost	(19,900 cubic meters) x ($1.00 per cubic meter) =	$19,900.00
	Abutment Cost	(2 standard abutments) x ($5,250.00 per abutment) =	$10,500.00
	Pier Cost	No pier =	$0.00
	Cable Anchorage Cost	No anchorages =	$0.00
Total Cost	**M + C + P + S**	**$143,755.25 + $21,000.00 + $6,000.00 + $77,400.00 =**	**$248,155.25**

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RESULTS PHASE 2: STRUCTURAL EFFICIENCY

The Warren Truss snapped at the floor beams and struts. This is probably because they were poorly placed when glued (not perpendicular). Every other part of the bridge was completely intact afterwards which leads us to suspect it could have held more weight if it was put together well. Overall the structural efficiency of this bridge was poor because it weighed 90.1 grams(0.199lb) and collapsed after 75.8 lbs.

Warren Truss Efficiency: 381

The Howe Truss broke at the floor beams and struts as well. This was most likely due to the poor placement of the struts and beams. Other than the beams and struts, the structure of the bridge was not damaged, and fully intact. Because the fame of the bridge was not damaged we are led to believe that, like the Warren Truss bridge, the bridge could have held more weight. Overall the structural efficiency of this bridge was good due to the fact that it only weighed 80.4 grams(0.177lb) and did not collapse until 84.2 lbs.

Howe Truss Efficiency: 476

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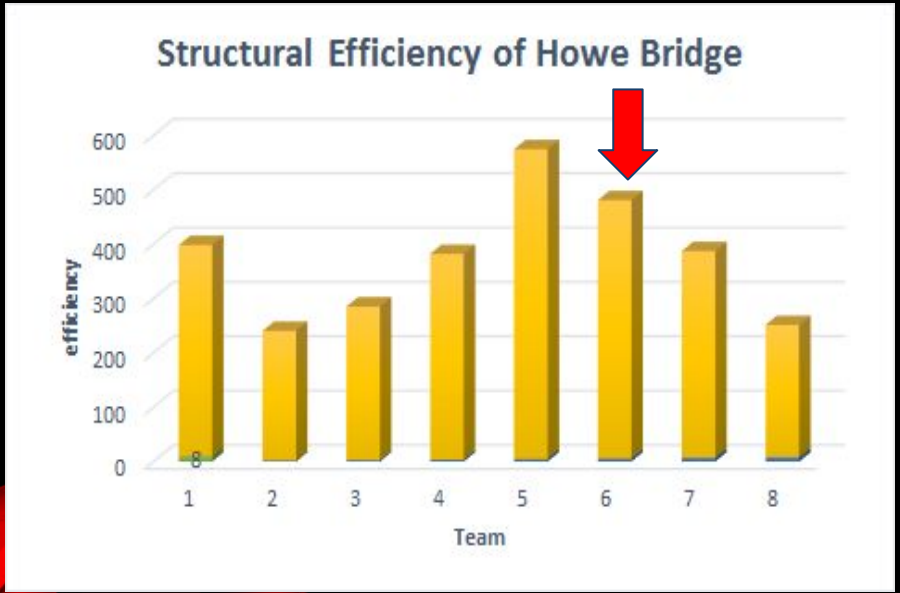
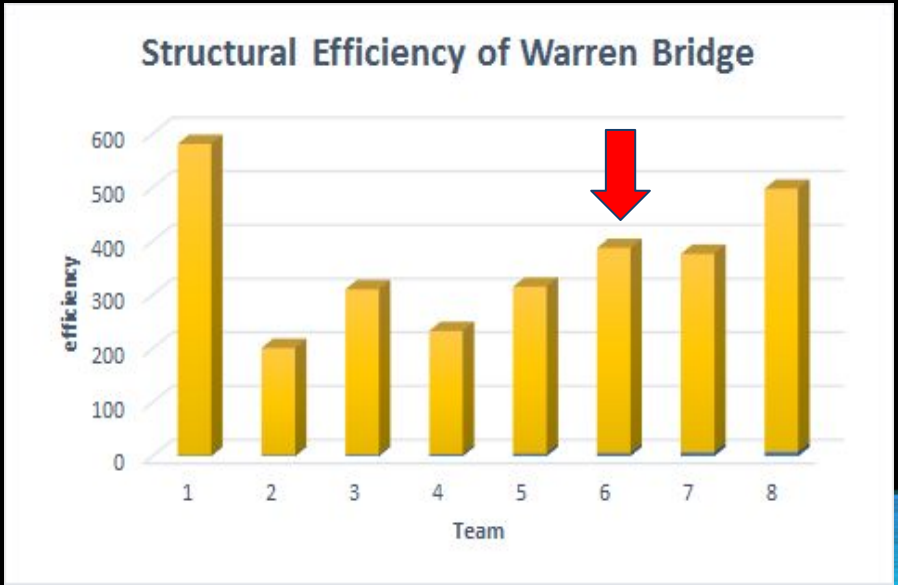
Comparison of Structural efficiency





Tables (structural efficiency):

Howe Bridge				
Design Team	Actual Bridge Weight (grams)	Estimated Load at Failure (lbs)	Load at Failure (lbs.)	Structural efficiency
1	81.3	74.23	69.78	389.3199658
2	64.3	20	33.8	238.4360861
3	95.8	50	59.6	282.1935011
4	78.5	30	65.4	377.897787
5	79.4	42	99.7	569.5618775
6	80.4	94	84.2	475.0313803
7	84.7	20	71	380.2254613
8	82.6	50	44.3	243.2707735

Warren Bridge				
Design Team	Actual Bridge Weight (grams)	Estimated Load at Failure (lbs)	Load at Failure (lbs.)	Structural efficiency
1	81.9	69	104.6	579.3140211
2	77.1	20	33.9	199.4396839
3	74.9	30	50.8	307.643789
4	75.7	30	38.2	228.8936478
5	80.9	60	55.4	310.6186302
6	90.1	97	75.8	381.6020259
7	87	30	70.9	369.6521526
8	83.6	31	90.3	489.9454512

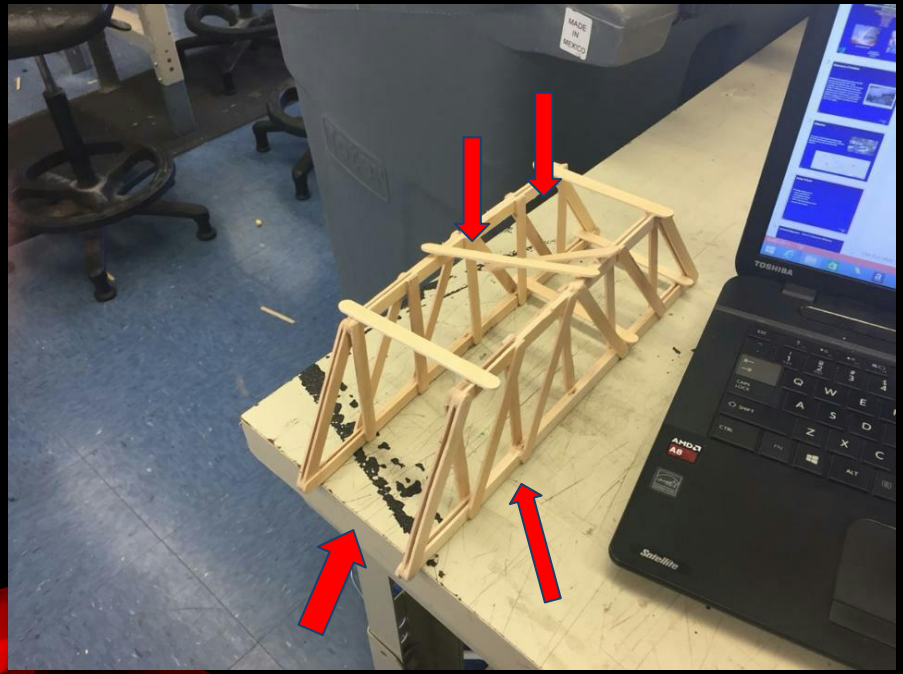
Howe Truss:

- Min: 238
- Max: 570
- Median: 379
- Range: 332

Warren Truss:

- Min: 199
- Max: 579
- Median: 340
- Range: 380

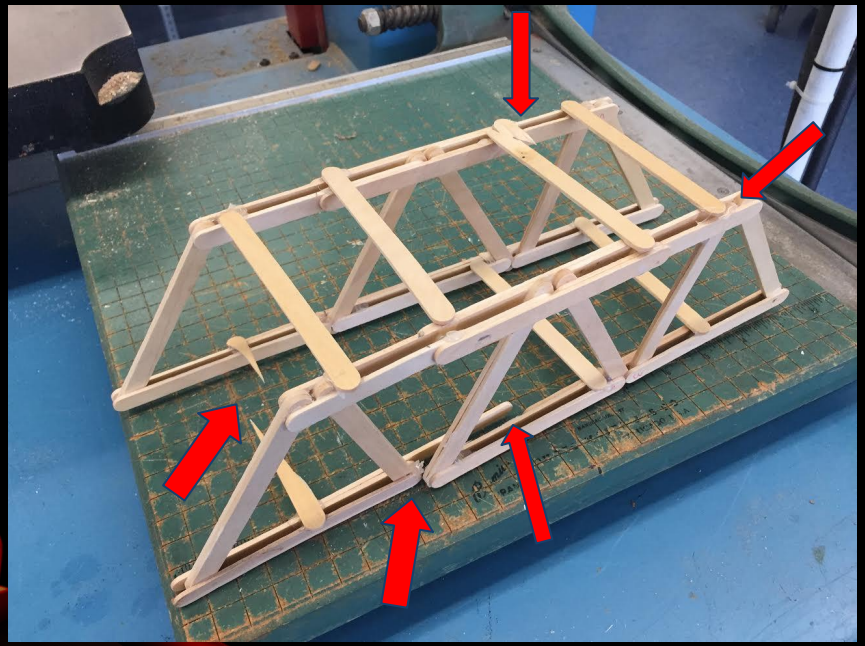
Howe Truss Bridge After Load Testing



Arrows to the structural members of the bridge that were damaged or shifted due to load testing.

- Two struts (top two arrows)
- Two floor beams (bottom two arrows)

Warren Truss Bridge After Load Testing



Arrows to the structural members of the bridge that were damaged or shifted due to load testing.

BEST SOLUTION

The best solution is a matter of debate:

- The *Warren Truss* was more economically efficient whereas the *Howe Truss* performed better structurally.
- Either bridge is a viable option. The decision comes down to Economics v. Strength.
- We would recommend the Howe Truss because it is less likely to be damaged and need to be prepared.

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CONCLUSIONS

We have come to the conclusion that even though the Warren Truss bridge would be more affordable, the Howe Truss would be the smarter decision. We have come to this decision because we would rather invest the extra money on a structurally efficient design, so that the likelihood of having to replace the bridge is not high.

- Installing the Warren truss bridge would be less costly, but it would be risky, and we would rather not take that risk.

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RECOMMENDATIONS

- Both the Warren and Howe Truss bridges were tested and the problem that occurred in both of the bridges was that the struts and the floor beams were not strong enough.
  - Ensure that the struts and the floor beams are strong enough to support the forces that will push down on them.
- Either bridge is a viable option. The decision comes down to Economics v. Strength

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