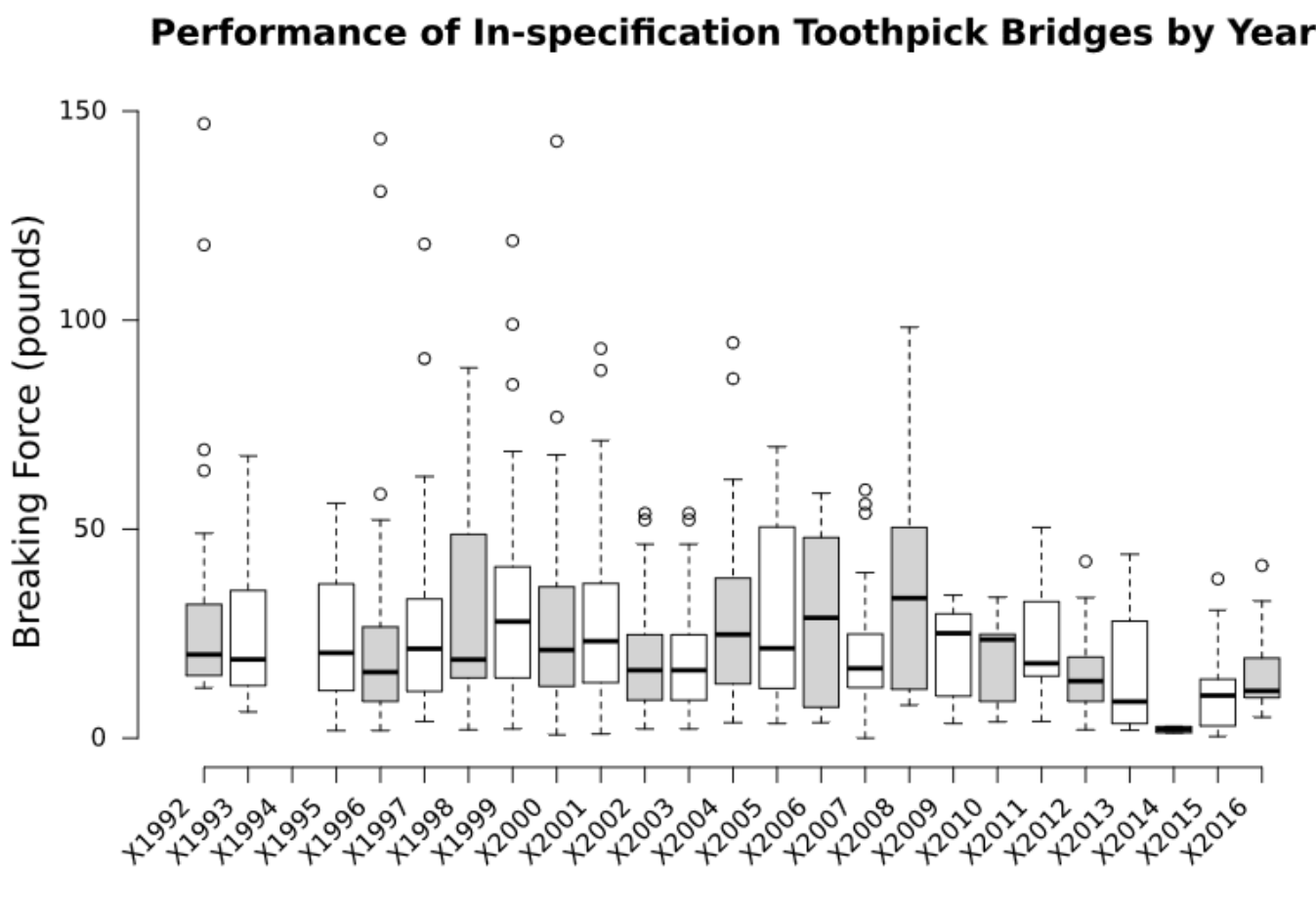
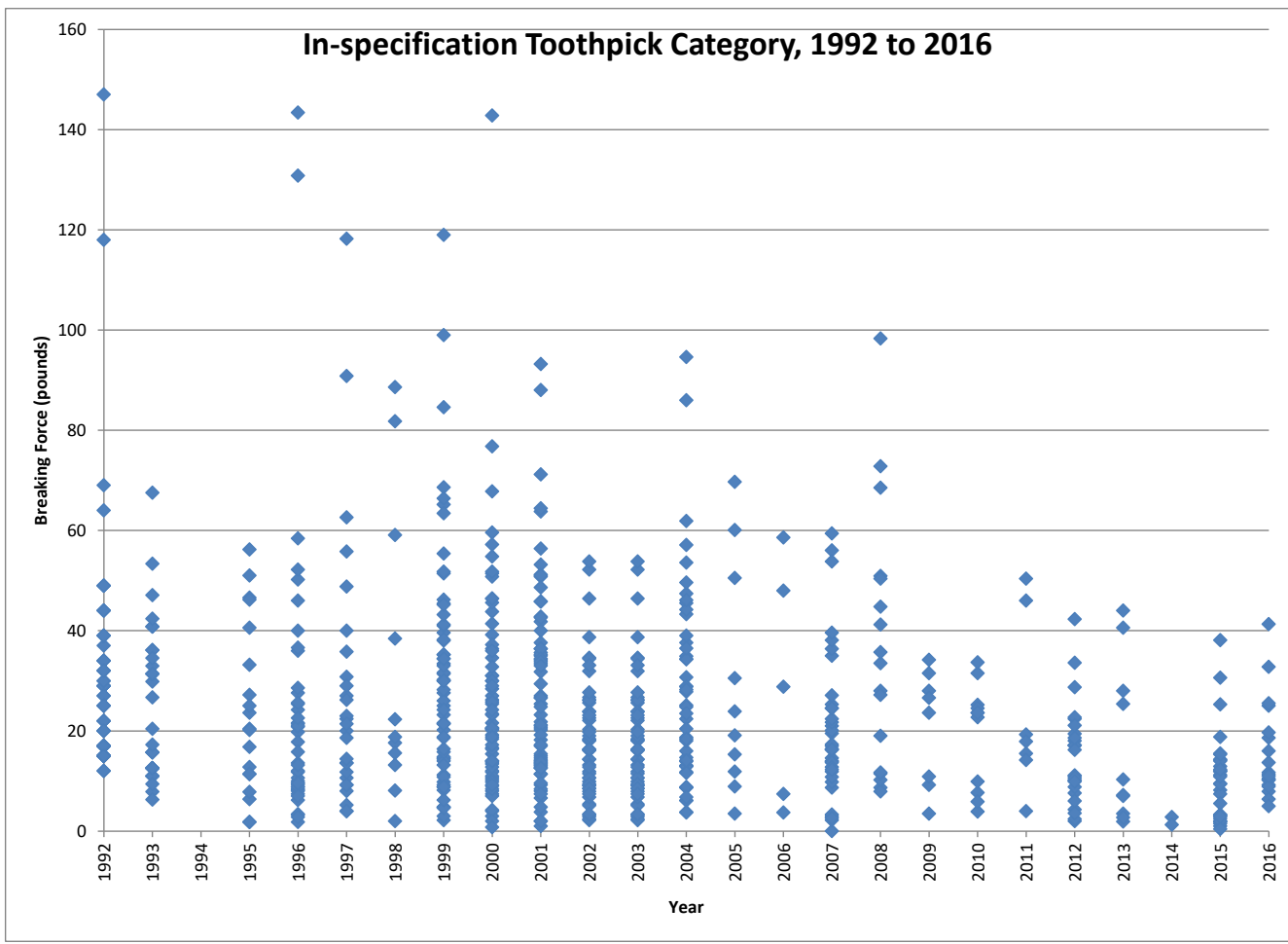


What glue should I use?

Toothpick Category Bridge Requirements

Materials: Wooden toothpicks and glue
Span = 16.625 inch
Length = span + 2 × bearing width
The bridge can weigh ≤121 grams.
Bridge type: Suspension bridge not allowed

The specifications say that the bridge must span 16 5/8 inches; how long should the bridge be?
The specifications don't give a design load; how much weight can a toothpick bridge this long support?
It just says glue; what kind of glue should I use?



Toothpick Bridge Building Event Bridge Specifications

Note to all event participants: PLEASE read all bridge specifications prior to starting construction of your bridge. Note that there are two construction categories to select from: Toothpick Category and Open-Materials Category. Since this is a destructive test, you may want to take a picture of your bridge before you come to the event.

Toothpick Category Bridge Specifications

Materials: You must use only wooden toothpicks and glue to build your bridge.

Weight: The bridge must not weigh more than 121 grams (4.27 ounces).

Overall dimensions:

Longest allowed length 64.77cm (25 1/2 in.)
Longest allowed width 17.78cm (7 in.)
Longest allowed height 45.72cm (18 in.)
(See drawings and photograph.)

Span: The bridge must span a gap or opening of 42.23cm (16 5/8 in.).
(See drawings and photograph.)

Type of Bridge: You may not build a hanging bridge or suspension bridge. The bridge must be free standing.

Load: A gradually increasing force (weight) will be applied to the bridge from above by 20.32 cm (8 in.) square or circular metal plate.

Support: The bridge will be supported from below by two metal brackets that are approximately 11.27 cm by 17.78 cm wide.

Roadbed: A surface or roadbed is not required.

Open-Materials Category Bridge Specifications

Materials: You may use any material to build your bridge.

Weight: The bridge must not weigh more than 60 grams (2.12 ounces).

Overall dimensions:

Longest allowed length 64.77cm (25 1/2 in.)
Longest allowed width 17.78cm (7 in.)
Longest allowed height 45.72cm (18 in.)
(See drawings and photograph.)

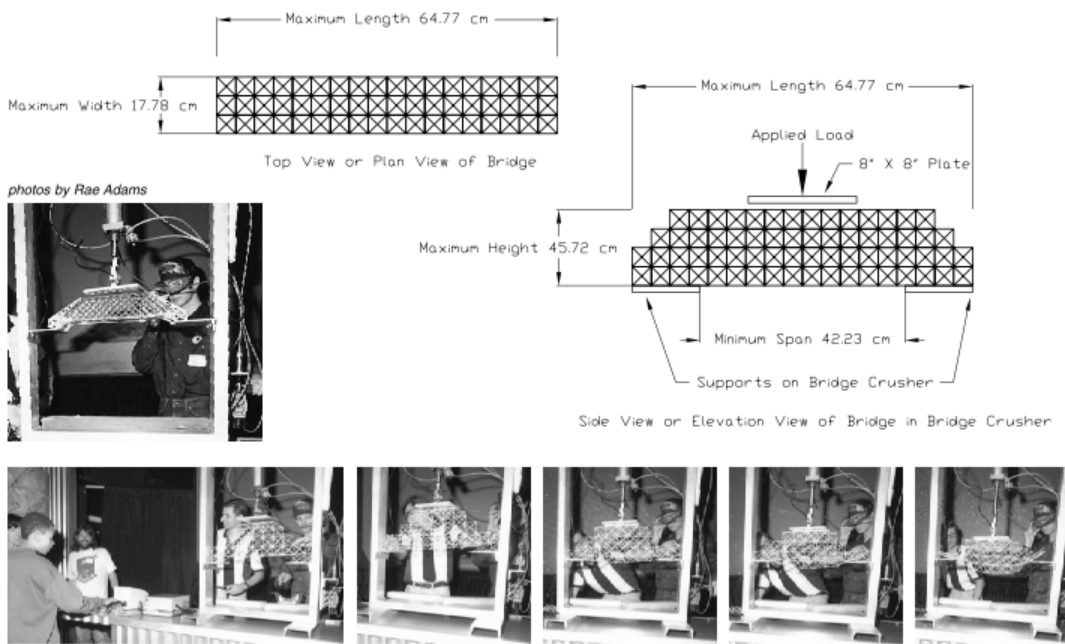
Span: The bridge must span a gap or opening of 42.23cm (16 5/8 in.).
(See drawings and photograph.)

Type of Bridge: You may not build a hanging bridge or suspension bridge. The bridge must be free standing.

Load: A gradually increasing force (weight) will be applied to the bridge from above by 20.32 cm (8 in.) square or circular metal plate.

Support: The bridge will be supported from below by two metal brackets that are approximately 11.27 cm by 17.78 cm wide.

Roadbed: A surface or roadbed is not required.



The median breaking force was less than 25 pounds every year except for three years.

The median breaking force was always less than 34 pounds.

However, prior to 2005, there were often bridges that held almost 100 pounds or more.

Some held as much as 140 pounds.

Last year, many teams used hot-melt glue; is that the strongest glue to use?



Fine Woodworking Magazine (FWM) tested six glues including carpenter's glue (**Polyvinyl acetate or PVA**) and polyurethane glue. There is a magazine article and video available on the web. They broke 162 specimens in their experiment. They ran a full-factorial experiment to learn the effects of three factors, glue type, fit of the joint, and species of wood. They fabricated the specimens in the magazine woodworking shop. They measured the breaking force on an instrument made for testing the strength of materials at a university.

FWM concluded that waterproof PVA and carpenter's PVA were the strongest of the glues that they tested.
FWM concluded that polyurethane glue was about 1/2 the strength of the PVA glues.

Schofield, Mark, How Strong is Your Glue, Fine Woodworking Magazine, No. 192, August 2007,

The Fine Woodworking Magazine experiment didn't test white glue (PVA) or superglue or hot melt glue or the wood itself.

How strong is white glue (PVA) or superglue (Cyanoacrylate or CA) or hot-melt glue?
How strong is the wood?



Experiment Design

Sequence	Random Block	Specimen S/N	Glue Type
1	Setup	SS	PVA, Type I
2	Setup	TT	PVA, Type I
3	S		
4	S		
5	S		
6	S		
7	S		
8	S		
9			
10			
11			
12			



Specimen Design & Fabrication Bonding Procedure



13	1	SA	No Joint
14	2	SB	No Joint
15	2	G	PVA, Yellow
16	2	J	CA
17	2	F	PVA, Type I
18	2	H	PVA, White
19	3	SC	No Joint
20	3	M	PVA, Yellow
21	3	N	PVA, White
22	3	L	PVA, Type I
23	3	P	CA
24	4	SD	No Joint
25	4	R	PVA, Type I
26	4	S	PVA, Yellow
27	4	T	PVA, White
28	4	U	CA
29	5	Y	PVA, White
30	5	SE	No Joint
31	5	Z	CA
32	5	X	PVA, Yellow
33	5	V	PVA, Type I
34	6	BB	PVA, Type I
35	6	EE	CA
36	6	DD	PVA, White
37	6	CC	PVA, Yellow
38	7	E	Hot Melt
39	7	K	Hot Melt
40	7	Q	Hot Melt
41	7	V	Hot Melt
42	7	AA	Hot Melt
43	7	FF	Hot Melt

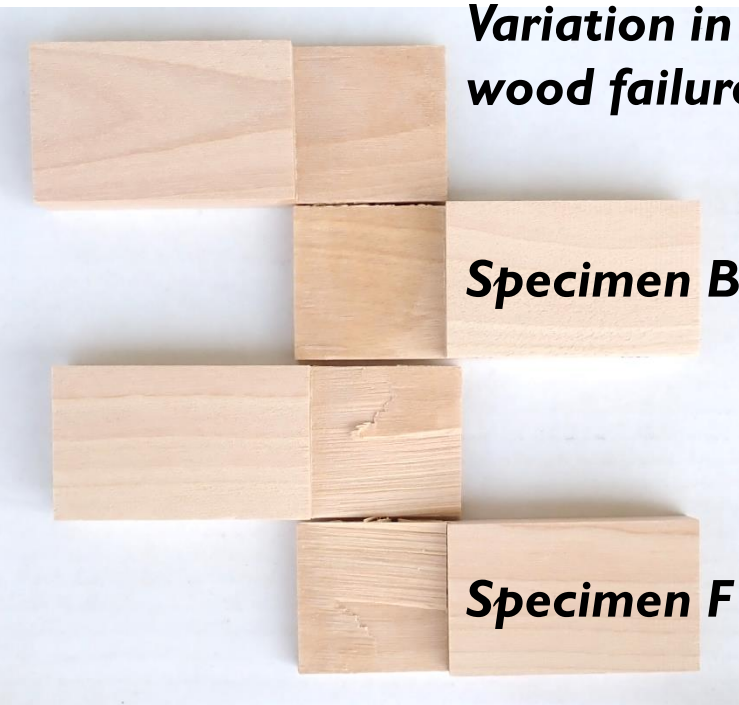
Extensio									
Tensile									
at									
1000 at									
Maximum									
Load									
Rate									
Type									
Sequence	Random	Specimen	Glue	Area	Maximum	Speed	Load	Rate	Type
	Block	S/N	Bond	in	Load	m/Load	at	mm/min	Glue
1	C	23881	2,080.47	0.07	0.08	933.081211	2079.568	PVA, White	
2	A	23907	2,070.30	0.07	0.07	933.284502	2075.168	PVA, Type I	
3	D	23892	1,626.96	0.07	0.07	733.700786	1625.827	CA	
4	B	23876	2,308.69	0.07	0.09	965.460726	2207.969	PVA, Yellow	
5	SA	23881	2,113.56	0.07	0.09	924.862129	2113.569	PVA, White	
6	SB	23881	1,057.58	0.07	0.11	1323.468851	1017.684	No Joint	
7	G	23877	2,390.03	0.07	0.09	1027.264603			
8	J	23816	1,778.89	0.07	0.08	771.124403			
9	F	23881	2,438.50	0.07	0.09	1065.474859			
10	H	23896	2,334.07	0.07	0.09	1022.034202			
11	SC	23897	1,613.19	0.07	0.07	705.170457			
12	M	23831	1,585.39	0.07	0.09	855.162864			
13	N	23786	1,950.35	0.07	0.07	855.946017			
14	L	23881	2,798.76	0.07	0.12	1210.364897			
15	P	23741	1,521.76	0.07	0.07	688.331389			
16	SD	23816	1,676.87	0.07	0.08	734.952229			
17	R	23736	2,165.74	0.07	0.09	952.9874279			
18	S	23881	1,958.80	0.07	0.08	856.961288			
19	T	23771	2,154.03	0.07	0.08	958.399576			
20	U	23480	1,583.72	0.07	0.07	688.279894			
21	Y	23710	2,140.37	0.07	0.08	945.544617			
22	SE	23771	1,134.08	0.07	0.12	1387.958355			
23	Z	23778	1,882.14	0.07	0.07	828.206201			
24	X	23786	2,314.60	0.07	0.08	1014.079634			
25	V	23710	2,233.02	0.07	0.08	983.248747			
26	BB	23786	2,415.06	0.07	0.09	1059.915034			
27	EE	23495	1,617.81	0.07	0.07	712.629487			
28	DD	23710	2,043.02	0.07	0.08	1081.132089			
29	CC	23725	2,134.06	0.07	0.08	984.861731			
30	Q	23207	673.3556	0.02	0.0402	293.852480			
31	K	23816	1,705.9648	0.035	0.0472	103.177762	765.2318	PVA, Hot	
32	V	23771	1,932.1476	0.035	0.0472	403.360762	951.4369	PVA, Hot	
33	AA	23710	1,908.28	0.035	0.04	397.562134	904.8389	PVA, Hot	
34	FF	23710	1,308.76	0.035	0.05	486.90368	1035.119	PVA, Hot	
35	FE	23443	1,255.25	0.035	0.07	553.830645	1254.724	PVA, Hot	

Least Squares Means Table

Level	Least Sq Mean	Std Error	Mean
CA	731.6903	58.598259	731.69
Hot Melt	409.9472	58.598259	409.95
No Joint	1011.2800	64.191177	1011.28
PVA, Type I	1052.2176	58.598259	1052.22
PVA, White	976.0153	58.598259	976.02
PVA, Yellow	937.9797	58.598259	937.98



Glues Tested



Variation in amount of wood failure PVA Type I

Specimen BB

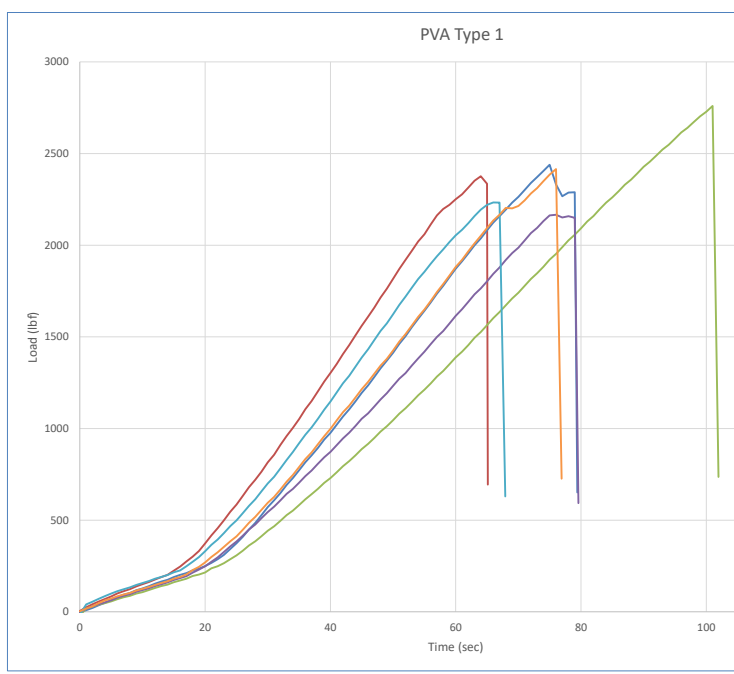
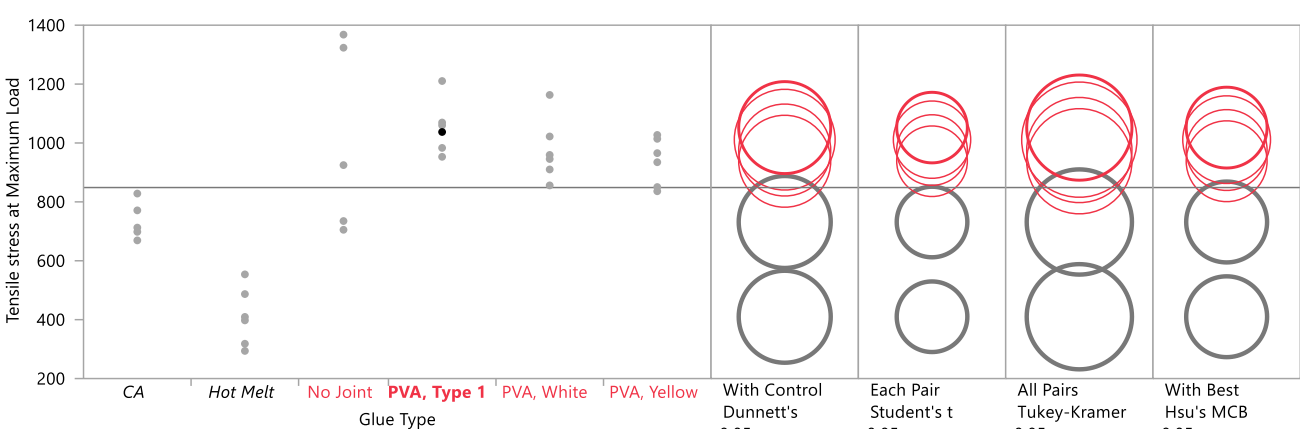
Specimen F

Preliminary Observations

Given the size of the standard deviations relative to the difference between means, additional calculations are required to state the confidence that one glue is stronger than another.

Comparison of means tests suggests that strength of the three PVA glues are indistinguishable from each other and from strength of wood.

PVA is stronger than CA which is stronger than hot-melt glue



Test Method and Equipment Test Plan & Testing



Georgia Institute of Technology
School of Civil and Environmental Engineering
Structures and Materials Laboratory

Contributors: Dante Dimenichi, Liam Renaghan, Dr. David Scott, Dr. Seo-Hun Lee, and Wiley Holcombe