

# **JON WEST RESEARCH PROJECT REPORT**

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## **OVERVIEW**

### **1. Project Background and Description**

*Exactly how strong are glued joints? That is the question that this research project would help to answer. I would like to systematically test the bonds and strengths of typical theatrical adhesives to substrates normally found in a scene shop. This data, enhanced by their SDS information would allow for the safe and secure use of adhesives in the typical scene shop.*

The above approved project description outlines what was undertaken in this research project. The project stayed true to this goal and ended up generating a good deal of data, as illustrated in the attached tables.

### **2. Project Process and Outcome**

The approved scope of this research project limited the number of samples to 45 discrete tests. As the project moved forward the number of test samples increased to provide a better representative sample size. The initial proposal had 3 test samples per combination, in actual testing this was increased to 4 for most combinations. Increasing the number of samples to 4 per combination allowed for a greater range of data, which would provide a more representative average that could take into account outliers. Additionally, the number of adhesives and substrates was increased to provide a more diverse representation of typical adhesives. The total number of tested samples, for which there is data, is 91. There were a few collection issues where data was lost due to operator error with the recording software.

As can be seen in the accompanying photos, each sample consisted of 2 pieces of substrate material that are 1-inch wide, which are then joined together with a 1-inch overlap.

It was decided early on that the testing samples should be created using “real world” techniques, not laboratory-style samples that abided by NDS standards. This means that when plywood was used, it was not sanded with 80-grit sandpaper to a smooth surface. Plywood was dusted off and then glue applied directly from the bottle, not measured, but

evenly spread across the surface of the joint and clamped with spring clamps. The resulting data would then reflect what more users could expect in their own glued joints. Metal samples were cleaned with shop-diluted Simple Green, as that is standard practice. UHMW samples were wiped down with Isopropyl Alcohol wipes, as that is recommended when using VHB Tapes.

The testing data was sorted by adhesive and then averaged. Each adhesive group had its data graphically processed to denote the hierarchy of which combination proved strongest. *It is important to note that the data collected is ONLY for the given samples in the tested orientation and IS NOT representative of all situations or manners in which the adhesive could be used.*

### 3. Takeaways

In regards to adhesive strengths, the largest surprise was the data that resulted from the combination of White Glue, Plywood, and Steel. In fact, White Glue outperformed Construction Adhesive when attaching Plywood to Steel, 331PSI to 256 PSI, respectively. Additionally, since they both PVA glues, these tests confirmed that White and Wood Glue are similar in strength as well as in chemical composition.

JB Weld is a strong adhesive for metal to metal bonds. The test samples which adhered Steel to Steel resulted in the only samples above 1000 PSI. The testing samples that adhered Aluminum to Aluminum showed that the adhesive is stronger than the connection of the piece. The aluminum tore out prior to failure of the adhesive joint.

As can be seen in the attached SDS Comparison Table, the adhesives tested were grouped into 3 generic categories; Red, Yellow, and Green. These colors were chosen as their hazards presented as malignant, mild, and benign (respectively).

There were no large surprises when looking at the data except for one aspect of the tested Construction Adhesive. Its worst aspect is that it is toxic for the liver if ingested chronically. This aspect should not be overlooked and the easiest way to avoid this hazard is by wearing the proper PPE when applying, such as Nitrile gloves.

### 4. Recommendations

Taking into account what is learned by comparing SDS data with the strength testing data, one recommendation is that users stay away from 2-Part Epoxy when possible. The data shows that it is strong and can adhere to most any substrate, but the health hazards should be taken into account, at the minimum proper PPE should be used.

PVA glues, such as White and Wood Glue, have shown that not only are they practically inert chemically, and they are strong as well. If possible, the use of these adhesives should be considered prior to moving on to more hazardous choices.

5. Photographs

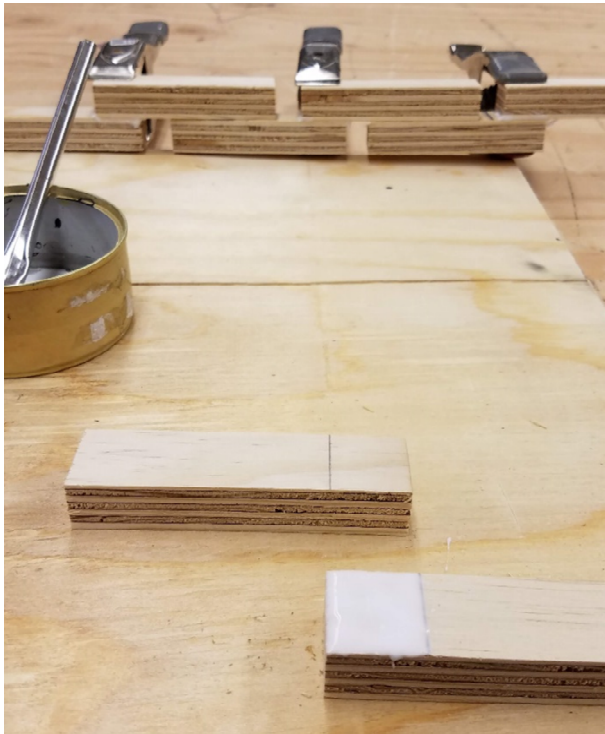


Figure 1. White Glue and plywood samples – typical

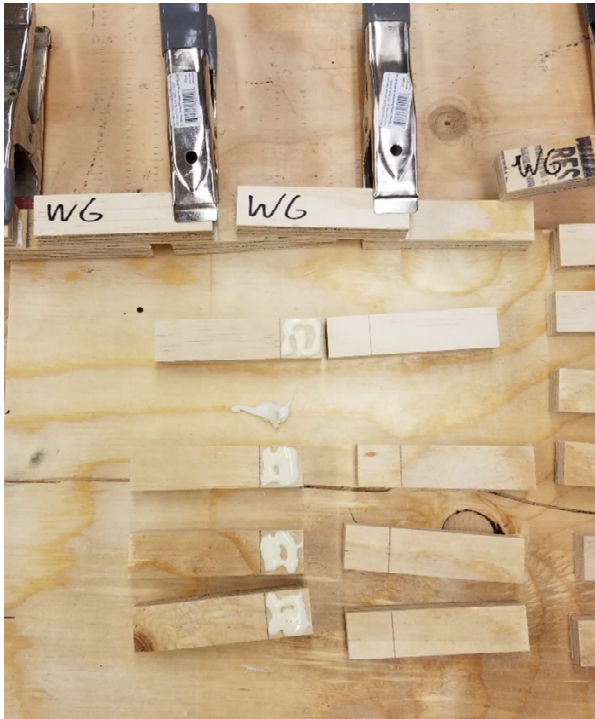


Figure 2. Wood Glue and plywood samples – typical

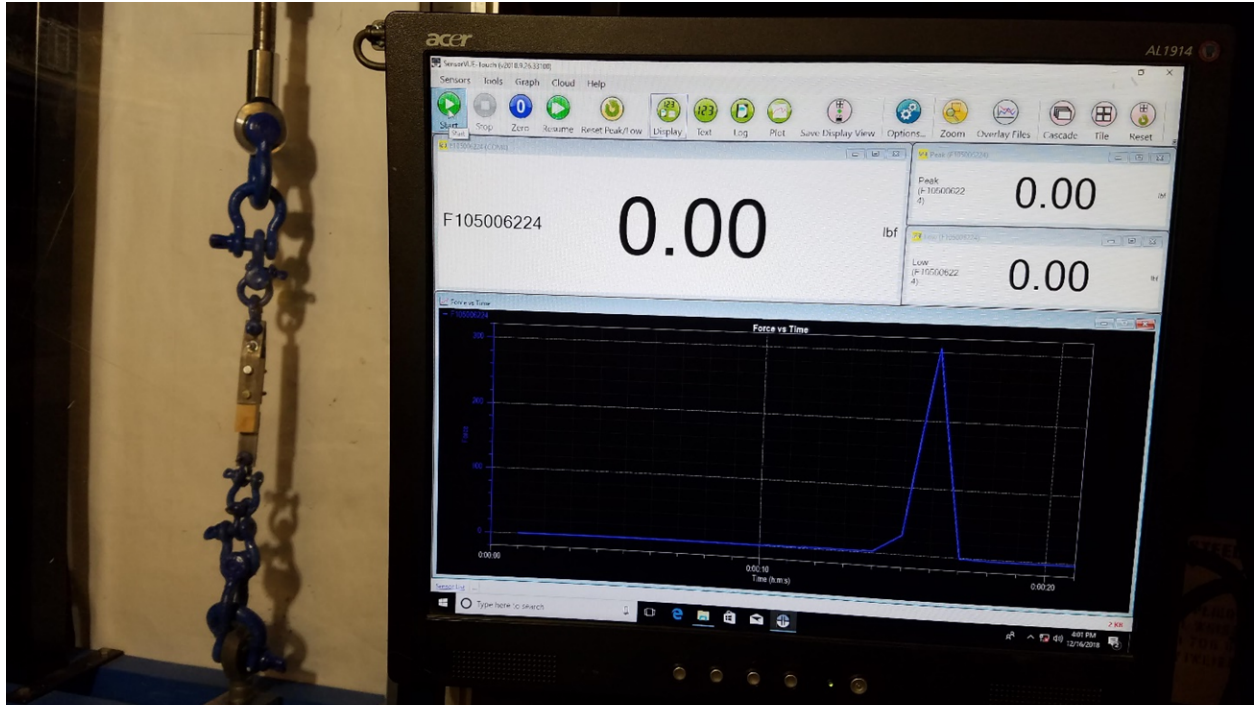


Figure 3. Typical testing set up













Figure 4. Aluminum to aluminum bonded with JB Weld, showing connection tear-out



### Adhesive Strengths - Data Collection

Sample #	Top Material	Bottom Substrate	Adhesive	Testing Orientation	Notes	Breaking Strength (PSI)	Avg. (PSI)
1	3/16" x 1" steel flat bar	3/16" x 1" steel flat bar	Construction Adhesive	Dynamic Overlap Shear	surface rust at joint	84.3	80
2	3/16" x 1" steel flat bar	3/16" x 1" steel flat bar	Construction Adhesive	Dynamic Overlap Shear	surface rust at joint	88.4	
3	3/16" x 1" steel flat bar	3/16" x 1" steel flat bar	Construction Adhesive	Dynamic Overlap Shear	surface rust at joint	68.5	
4	3/4" Plywood	3/16" x 1" steel flat bar	Construction Adhesive	Dynamic Overlap Shear		247.2	256
5	3/4" Plywood	3/16" x 1" steel flat bar	Construction Adhesive	Dynamic Overlap Shear		158.7	
6	3/4" Plywood	3/16" x 1" steel flat bar	Construction Adhesive	Dynamic Overlap Shear		272.4	
7	3/4" Plywood	3/16" x 1" steel flat bar	Construction Adhesive	Dynamic Overlap Shear	minor substrate failure	345.2	
8	3/4" Plywood	3/4" Plywood	Construction Adhesive	Dynamic Overlap Shear		357.15	315
9	3/4" Plywood	3/4" Plywood	Construction Adhesive	Dynamic Overlap Shear	severe substrate failure	422.56	
10	3/4" Plywood	3/4" Plywood	Construction Adhesive	Dynamic Overlap Shear	no substrate failure	318.3	
11	3/4" Plywood	3/4" Plywood	Construction Adhesive	Dynamic Overlap Shear	severe substrate failure	160.78	
12	3/16" x 1" steel flat bar	3/16" x 1" steel flat bar	Contact Adhesive	Dynamic Overlap Shear	surface rust at joint	103.07	97
13	3/16" x 1" steel flat bar	3/16" x 1" steel flat bar	Contact Adhesive	Dynamic Overlap Shear	surface rust at joint	72.48	
14	3/16" x 1" steel flat bar	3/16" x 1" steel flat bar	Contact Adhesive	Dynamic Overlap Shear	surface rust at joint	143.07	
15	3/16" x 1" steel flat bar	3/16" x 1" steel flat bar	Contact Adhesive	Dynamic Overlap Shear	surface rust at joint	68.56	
16	3/4" Plywood	3/16" x 1" steel flat bar	Contact Adhesive	Dynamic Overlap Shear		48.1	130
17	3/4" Plywood	3/16" x 1" steel flat bar	Contact Adhesive	Dynamic Overlap Shear	steel bond failure	218.2	
18	3/4" Plywood	3/16" x 1" steel flat bar	Contact Adhesive	Dynamic Overlap Shear	steel bond failure	123.4	
19	3/4" Plywood	3/4" Plywood	Contact Adhesive	Dynamic Overlap Shear		180.22	212
20	3/4" Plywood	3/4" Plywood	Contact Adhesive	Dynamic Overlap Shear	single side bond failure	241.79	
21	3/4" Plywood	3/4" Plywood	Contact Adhesive	Dynamic Overlap Shear		196.32	
22	3/4" Plywood	3/4" Plywood	Contact Adhesive	Dynamic Overlap Shear	single side bond failure	228.38	
23	3/16" x 1" steel flat bar	3/16" x 1" steel flat bar	Epoxy	Dynamic Overlap Shear		218.73	345
24	3/16" x 1" steel flat bar	3/16" x 1" steel flat bar	Epoxy	Dynamic Overlap Shear		396.51	
25	3/16" x 1" steel flat bar	3/16" x 1" steel flat bar	Epoxy	Dynamic Overlap Shear		284.19	
26	3/16" x 1" steel flat bar	3/16" x 1" steel flat bar	Epoxy	Dynamic Overlap Shear		482.2	
27	3/4" Plywood	3/16" x 1" steel flat bar	Epoxy	Dynamic Overlap Shear	minor substrate failure	118.65	248
28	3/4" Plywood	3/16" x 1" steel flat bar	Epoxy	Dynamic Overlap Shear	minor substrate failure	188.66	
29	3/4" Plywood	3/16" x 1" steel flat bar	Epoxy	Dynamic Overlap Shear	minor substrate failure	249.56	
30	3/4" Plywood	3/16" x 1" steel flat bar	Epoxy	Dynamic Overlap Shear	severe substrate failure	435.93	
31	3/4" Plywood	3/4" Plywood	Epoxy	Dynamic Overlap Shear	minor substrate failure	264.03	290
32	3/4" Plywood	3/4" Plywood	Epoxy	Dynamic Overlap Shear	minor substrate failure	285.93	
33	3/4" Plywood	3/4" Plywood	Epoxy	Dynamic Overlap Shear	minor substrate failure	252.16	
34	3/4" Plywood	3/4" Plywood	Epoxy	Dynamic Overlap Shear	severe substrate failure	357.84	
35	3/16" x 1" steel flat bar	3/16" x 1" steel flat bar	JB Weld	Dynamic Overlap Shear		2207.75	1826
36	3/16" x 1" steel flat bar	3/16" x 1" steel flat bar	JB Weld	Dynamic Overlap Shear		1731.55	
37	3/16" x 1" steel flat bar	3/16" x 1" steel flat bar	JB Weld	Dynamic Overlap Shear		1792.54	
38	3/16" x 1" steel flat bar	3/16" x 1" steel flat bar	JB Weld	Dynamic Overlap Shear		1571.02	
39	3/4" Plywood	.0625" x 1" Aluminum	JB Weld	Dynamic Overlap Shear	severe substrate failure	277.12	413
40	3/4" Plywood	.0625" x 1" Aluminum	JB Weld	Dynamic Overlap Shear	severe substrate failure	339.17	
41	3/4" Plywood	.0625" x 1" Aluminum	JB Weld	Dynamic Overlap Shear	severe substrate failure	623.4	
42	.0625" x 1" Aluminum	.0625" x 1" Aluminum	JB Weld	Dynamic Overlap Shear	connection tear out	864.87	862
43	.0625" x 1" Aluminum	.0625" x 1" Aluminum	JB Weld	Dynamic Overlap Shear	connection tear out	858.56	
44	3/16" x 1" steel flat bar	3/4" Plywood	JB Weld	Dynamic Overlap Shear	severe substrate failure	363.08	452
45	3/16" x 1" steel flat bar	3/4" Plywood	JB Weld	Dynamic Overlap Shear	severe substrate failure	144.87	
46	3/16" x 1" steel flat bar	3/4" Plywood	JB Weld	Dynamic Overlap Shear	severe substrate failure	847.68	
47	3/16" x 1" steel flat bar	.0625" x 1" Aluminum	JB Weld	Dynamic Overlap Shear	connection tear out	620	620
48	3/4" Plywood	1/2" UHMW	VHB Tape	Dynamic Overlap Shear	clean tape separation	36.87	36
49	3/4" Plywood	1/2" UHMW	VHB Tape	Dynamic Overlap Shear	clean tape separation	24.35	
50	3/4" Plywood	1/2" UHMW	VHB Tape	Dynamic Overlap Shear	clean tape separation	53.34	
51	3/4" Plywood	1/2" UHMW	VHB Tape	Dynamic Overlap Shear	clean tape separation	30.5	
52	.125" x 1" Aluminum	3/16" Steel	VHB Tape	Dynamic Overlap Shear	severe tape tear out	106.11	93
53	.125" x 1" Aluminum	3/16" Steel	VHB Tape	Dynamic Overlap Shear	severe tape tear out	71.46	
54	.125" x 1" Aluminum	3/16" Steel	VHB Tape	Dynamic Overlap Shear	severe tape tear out	75.07	
55	.125" x 1" Aluminum	3/16" Steel	VHB Tape	Dynamic Overlap Shear	severe tape tear out	120	
56	.0625" x 1" Aluminum	.0625" x 1" Aluminum	VHB Tape	Dynamic Overlap Shear	severe tape tear out	66.62	64
57	.0625" x 1" Aluminum	.0625" x 1" Aluminum	VHB Tape	Dynamic Overlap Shear	severe tape tear out	34.95	
58	.0625" x 1" Aluminum	.0625" x 1" Aluminum	VHB Tape	Dynamic Overlap Shear	severe tape tear out	91.68	
59	3/16" Steel	1/2" UHMW	VHB Tape	Dynamic Overlap Shear	clean tape separation	20.28	28
60	3/16" Steel	1/2" UHMW	VHB Tape	Dynamic Overlap Shear	clean tape separation	41.76	
61	3/16" Steel	1/2" UHMW	VHB Tape	Dynamic Overlap Shear	clean tape separation	30.66	
62	3/16" Steel	1/2" UHMW	VHB Tape	Dynamic Overlap Shear	clean tape separation	18.44	
63	3/16" Steel	3/16" Steel	VHB Tape	Dynamic Overlap Shear	severe tape tear out	143.29	139
64	3/16" Steel	3/16" Steel	VHB Tape	Dynamic Overlap Shear	severe tape tear out	141.72	
65	3/16" Steel	3/16" Steel	VHB Tape	Dynamic Overlap Shear	severe tape tear out	118.93	
66	3/16" Steel	3/16" Steel	VHB Tape	Dynamic Overlap Shear	severe tape tear out	150.69	
67	3/4" Plywood	3/4" Plywood	White Glue	Dynamic Overlap Shear		207.59	291
68	3/4" Plywood	3/4" Plywood	White Glue	Dynamic Overlap Shear	minor substrate failure	323.82	
69	3/4" Plywood	3/4" Plywood	White Glue	Dynamic Overlap Shear	severe substrate failure	399.06	
70	3/4" Plywood	3/4" Plywood	White Glue	Dynamic Overlap Shear		231.73	
71	3/4" Plywood	3/16" Steel	White Glue	Dynamic Overlap Shear	no substrate failure	305.93	331
72	3/4" Plywood	3/16" Steel	White Glue	Dynamic Overlap Shear	no substrate failure	133.4	
73	3/4" Plywood	3/16" Steel	White Glue	Dynamic Overlap Shear	no substrate failure	333.93	
74	3/4" Plywood	3/16" Steel	White Glue	Dynamic Overlap Shear	no substrate failure	550.75	
75	3/16" Steel	3/16" Steel	White Glue	Dynamic Overlap Shear		341.87	210
76	3/16" Steel	3/16" Steel	White Glue	Dynamic Overlap Shear		66.48	
77	3/16" Steel	3/16" Steel	White Glue	Dynamic Overlap Shear		260.52	
78	3/16" Steel	3/16" Steel	White Glue	Dynamic Overlap Shear		172.37	
79	3/16" x 1" steel flat bar	3/16" x 1" steel flat bar	Wood Glue	Dynamic Overlap Shear		36.53	28
80	3/16" x 1" steel flat bar	3/16" x 1" steel flat bar	Wood Glue	Dynamic Overlap Shear		19.35	
81	3/4" Plywood	3/16" x 1" steel flat bar	Wood Glue	Dynamic Overlap Shear	severe substrate failure	204.91	109
82	3/4" Plywood	3/16" x 1" steel flat bar	Wood Glue	Dynamic Overlap Shear	minor substrate failure	59.08	
83	3/4" Plywood	3/16" x 1" steel flat bar	Wood Glue	Dynamic Overlap Shear	minor substrate failure	98.38	
84	3/4" Plywood	3/16" x 1" steel flat bar	Wood Glue	Dynamic Overlap Shear	minor substrate failure	73.97	
85	3/4" Plywood	3/4" Plywood	Wood Glue	Dynamic Overlap Shear	minor substrate failure	333.96	375
86	3/4" Plywood	3/4" Plywood	Wood Glue	Dynamic Overlap Shear	minor substrate failure	342.61	
87	3/4" Plywood	3/4" Plywood	Wood Glue	Dynamic Overlap Shear	severe substrate failure	492.79	
88	3/4" Plywood	3/4" Plywood	Wood Glue	Dynamic Overlap Shear	minor substrate failure	330.57	

### Jon West - Research Project - SDS Comparison Data

Adhesive type	Company	Product Name / Code	Cost per square inch	GHS SDS Symbols	VOC Content (g/l)	US - California Prop 65 Carcinogens List	US - California Prop 65 Developmental Toxicity	US - California Prop 65 Reproductive Toxicity - Female	US - California Prop 65 Reproductive Toxicity - Male	Other Chemicals of Note	
Tape	3M	VHB Tape 4905	\$ 0.08	This product is an article and therefore not subject to the requirements of US OSHA Hazardous Communications Standard 29 CFR 1910.1200(b)(6)(v) to provide a Safety Data Sheet.							
Liquid Glue	Elmer's	Glue-All (white glue)	\$ 0.0015	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Liquid Glue	Elmer's	Carpenter's Wood Glue	\$ 0.0016	N/A	N/A	N/A	N/A	N/A	N/A	N/A	
Construction Adhesive	Titebond (Franklin International)	GREENchoice Heavy Duty Construction Adhesive	\$ 0.01		38.5	N/A	N/A	N/A	N/A	Ethanediol	
2-Part Epoxy	J-B Weld	Steel Reinforced Epoxy Resin - Twin Tubes Slow Cure (Part B - Hardener)	\$ 0.08		<1% of volume	Titanium Dioxide; Crystalline Silica non-respirable	N/A	N/A	N/A	Benzyl alcohol; 2,4,6-tris (dimethylaminomethyl)phenol	
2-Part Epoxy	J-B Weld	Steel Reinforced Epoxy Resin - Twin Tubes (Part A - Steel)	\$ 0.08		<1% of volume	Crystalline Silica non-respirable; Carbon Black respirable	N/A	N/A	N/A	Epichlorohydrin	
Contact Adhesive	Wilsonart	H2O	\$ 0.001		20	2-Chloro-1,3-butadiene (126-99-8); Formaldehyde (50-00-0); Quinoline (91-22-5); Naphthalene (91-20-3)	N/A	N/A	N/A	Potassium hydroxide; Zinc oxide	
2-Part Epoxy	West System	105 Resin	\$ 0.0026	 	N/A	Epichlorohydrin (106-89-8)	N/A	N/A	Epichlorohydrin (106-89-8)	Benzyl alcohol	
2-Part Epoxy	West System	205 Fast Hardener	\$ 0.0026	   	7.91	N/A	N/A	N/A	N/A	Formaldehyde; Amines, polyethylenepoly; Ethanediamine; Phenol; Triethylenetetramine; Tetraethylenepentamine	