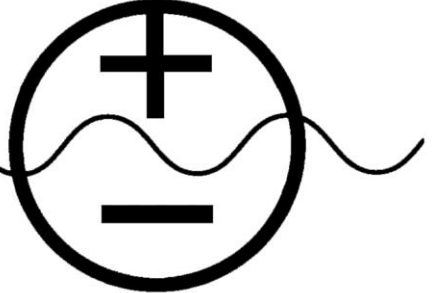


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and Associates Australia

CORROSION ENGINEERS

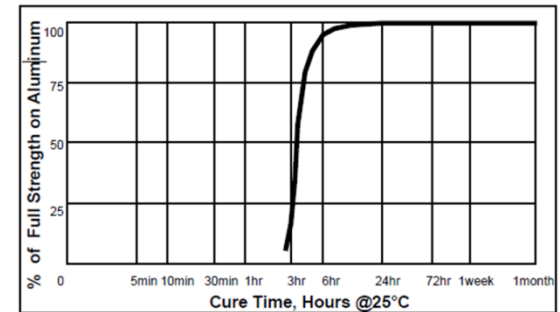
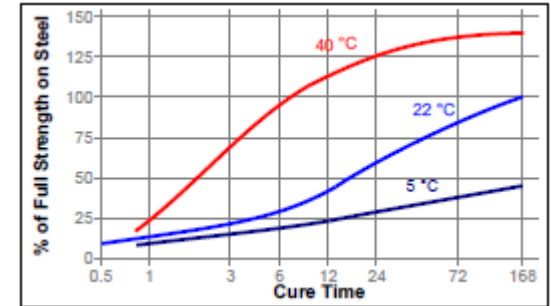
Don't Let Your Pull Go to Waste, Use the Right Glue

Test Results for Glues Used for Adhesion Testing to AS 3894.9 Method C

Kingsley Brown

Aim

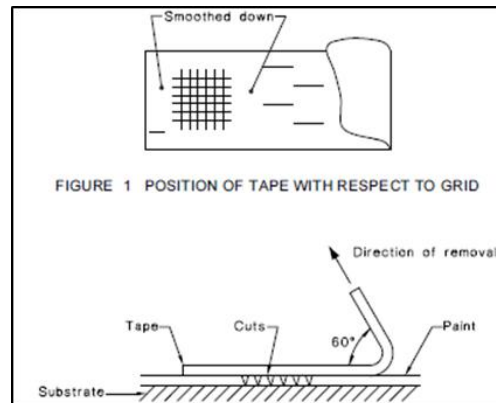
- The paper and experimentation looks at the pull-off values of a range of:
 - 8 readily available glues
 - 11 time intervals
- Search for a product which provide reliable results in the shortest period of time
- Expected results
 - Steady increase of force vs. time (graph)
 - Blasted substrate will allow for higher adhesion
 - Low cost practical paper with usable results



Adhesion Testing

- Site testing of protective coatings Method 9: Determination of adhesion 2003

| Test | AS 3894 | AS/NZS 1580.408 | ASTM |
|-----------|----------|-----------------|-------|
| Knife | Method A | .2 | D6677 |
| Cross-cut | Method B | .4 | D3359 |
| Pull-off | Method C | .5 | D4541 |



Pull off Adhesion Testing

- Determines the greatest perpendicular force (in tension) that a surface can withstand before a plug of material is detached
- Limited by:
 - Adhesion of dolly to glue
 - Glue to coating
 - Cohesive strength of the coating system
 - Cohesive strength of the substrate

Why do you need the right glue

- Many cases where adhesive failures have lead a result being obtained.
 - Dollies fall off while curing
 - Dollies do not fully adhere
 - Failure of the glue occurs while cutting
 - The force achieved is below the pass fail criteria
- Adhesion testing is normally a two day exercise
 - Day one gluing the dollies
 - Waiting overnight for the glue to cure
 - Then returning the following day to pull the dollies and reporting.
- Remote locations the 24 hour cure time adds significant cost
 - Inspector wages
 - Accommodation
 - Travel costs.



Method

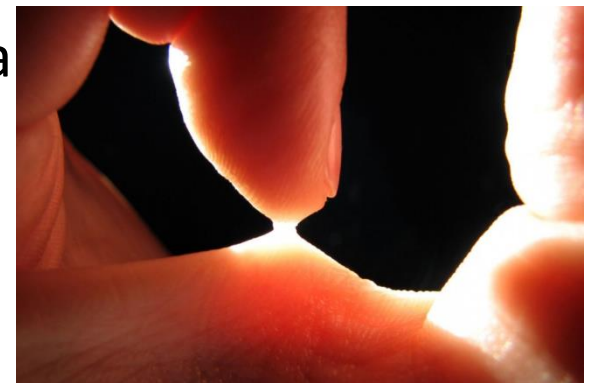
Adhesive

A suitable high-strength solvent-free adhesive that does not interact with the coating and has a tensile bond strength greater than the test requirement. A typical adhesive is a solventfree 2-pack high-strength epoxy adhesive.



Expected Coating Adhesion Values

- Steel
 - New 8 MPa
 - Overcoat 4-5 MPa
- Concrete
 - 1 MPa
- Typical Tensile Strengths
 - Steel 400-500 MPa
 - Epoxy adhesive 12-30 MPa
 - Concrete 3 MPa
 - Human skin 20 MPa



Test Panels

- Panels
 - Blasted
 - Profile 38 microns
 - Primer
 - Dulux GPE ZP
 - DFT 221 microns
 - Topcoat
 - Dulux WeatherMax HBR
 - DFT 96 microns (317 total)
- 326 Dollies
- 11 Cure Times
 - 5 min
 - 10 min
 - 30 min
 - 1 hour
 - 2 hour
 - 4 hour
 - 8 hour
 - 16 hour
 - 24 hour
 - 48 hour
 - 72 hour



Adhesives

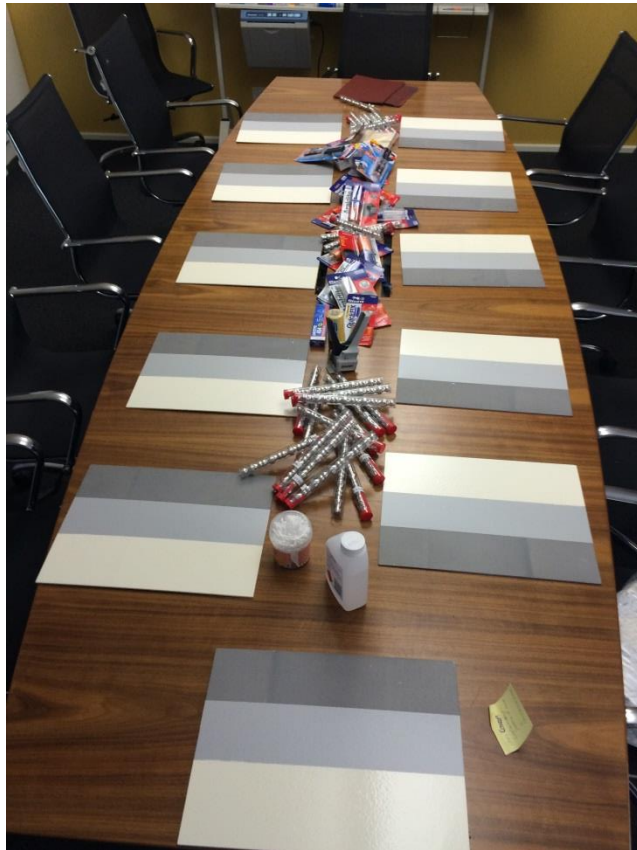
| Adhesive | Cost |
|------------------------------|----------|
| QuickFIX Gel Supa glue | \$ 4.79 |
| Loctite 454 Instant Adhesive | \$ 18.00 |
| 90 Seconds | \$ 20.95 |
| 5 min | \$ 9.49 |
| Ezy Repair 5 minute | \$ 6.22 |
| Ultra Clear | \$ 16.25 |
| Super Strength | \$ 12.55 |
| Loctite 4090 Hybrid Adhesive | \$ 69.00 |



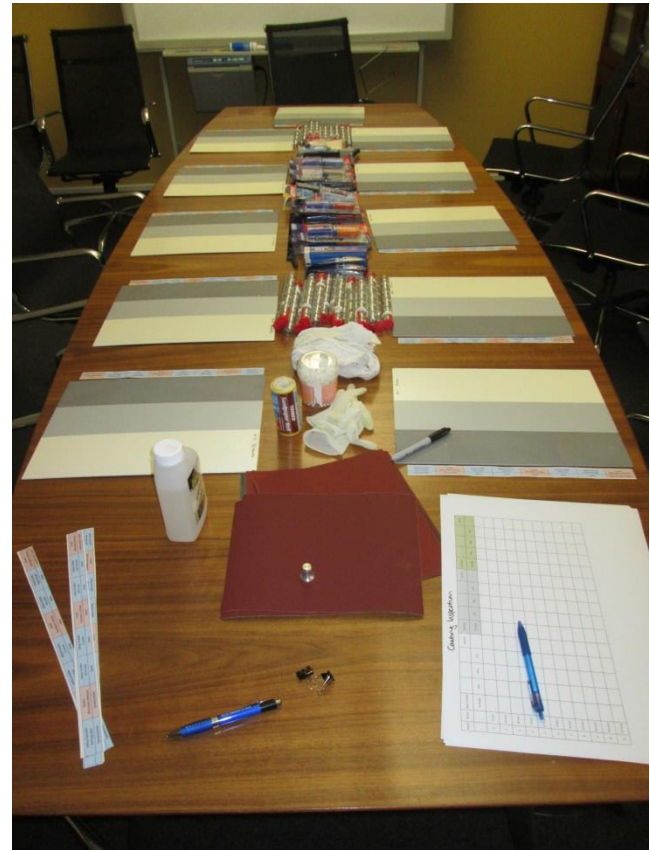
| Adhesive | Max Strength N/mm2 | Working | Set | Full cure |
|------------------------------|--------------------------|----------|-----------|-----------|
| QuickFIX Gel Supa glue | - | - | - | - |
| Loctite 454 Instant Adhesive | 11-19 shear | 2-10 sec | 40 sec | 1 min |
| 90 Seconds | 12-15 | 90 sec | 5 min | 16 hours |
| 5 min | 12-15 | 3-5 min | 20 min | 16 hours |
| Ezy Repair 5 minute | - | - | - | - |
| Ultra Clear | 12-15 | 5 min | 20 min | 16 hours |
| Super Strength | 17 | 2 hours | 6-8 hours | 3 days |
| Loctite 4090 Hybrid Adhesive | 7.1 tensile | 25 Sec | - | 1 week |
| Loctite Hysol E-20HP | 28 Shear 39.3 tensile | 20 mi | 3-6 hours | 24 hours |

Preparation

Boss Setup



Engineer Setup



Coating Inspection

Surface profile



DFT

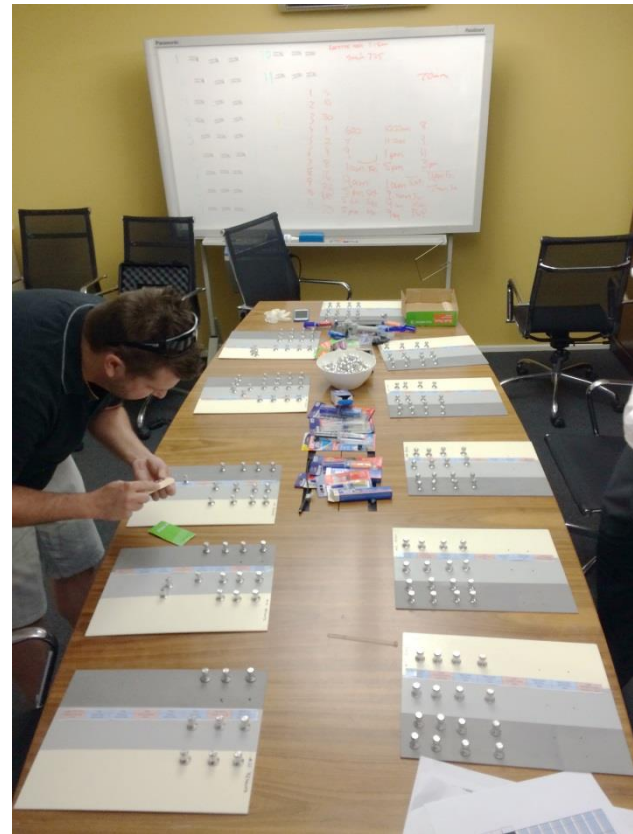


Gluing

Degreasing



Gluing

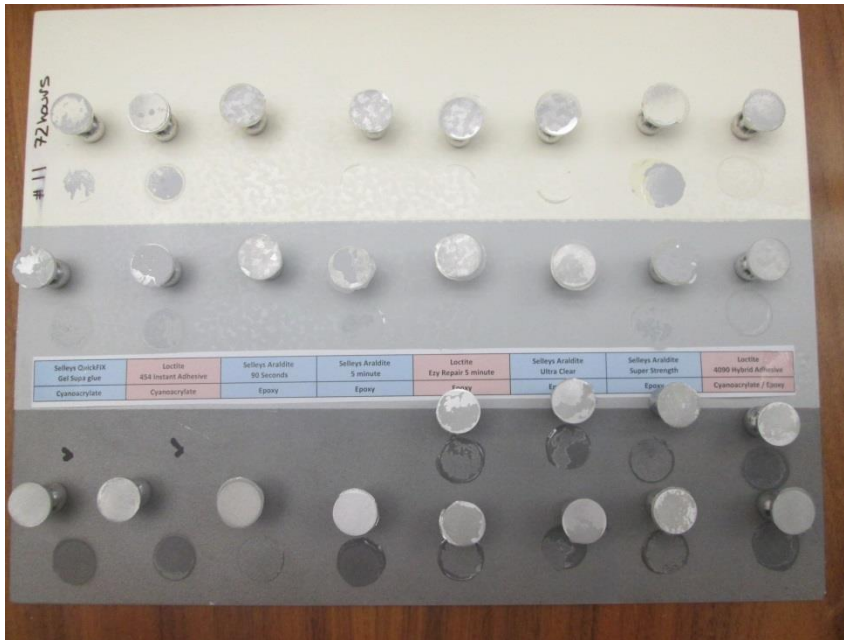


Pulling

- 20mm Dollies
- Pull rate 0.70 MPa
- Resolution: 0.01 MPa
- Accuracy: $\pm 1\%$ Full Scale
- Calculates pressure based on dolly size
- Maximum pull of pressure 20 MPa



Recorded Results



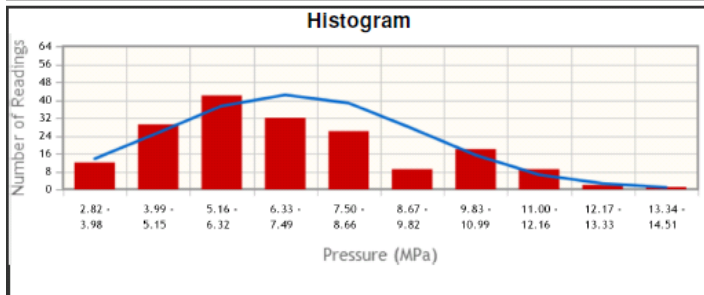
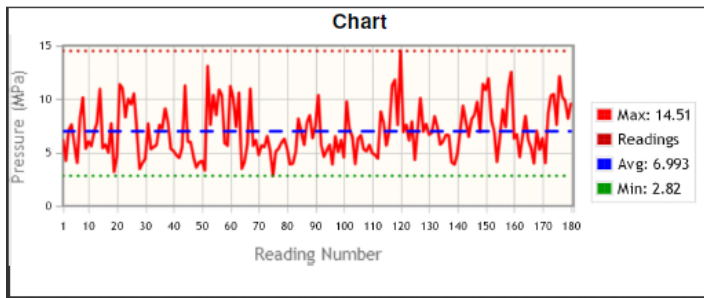
- Time of start / stop gluing
- Time of start / stop pulling
- Force for each dolly
- Major failure mode
- Batch of pulls



Positest AT-A Results

| Header | | | |
|--------------|------|-------------|---------------------|
| Batch Name: | B1 | Batch Date: | 2015-02-23 09:31:47 |
| Gage S/N: | 8669 | | |
| Probe Type: | AT-A | Probe S/N: | Probe S/N |
| Cal: | Cal | Substrate: | Substrate |
| Batch Notes: | | | |

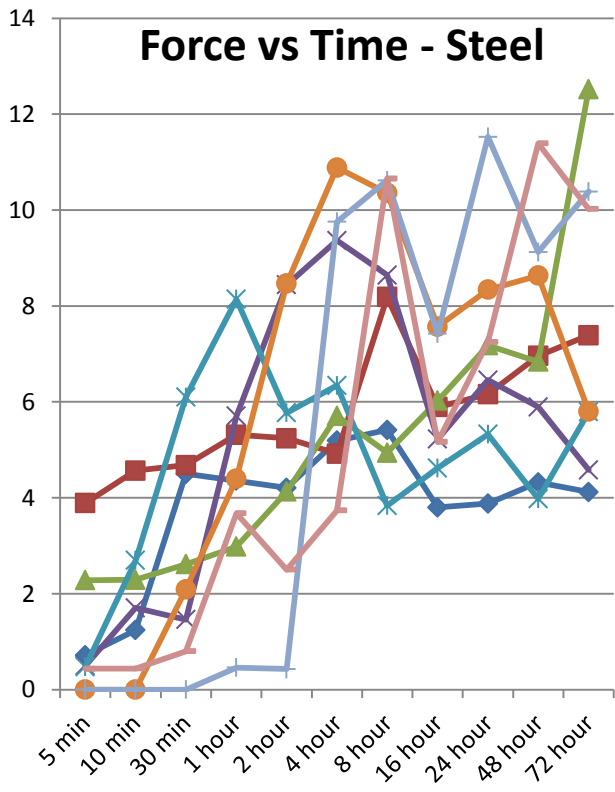
| Summary | | | | | |
|---------|-----|-------|-------|------|-------|
| | # | X | σ | μ | ↑ |
| B1 | 180 | 6.993 | 2.353 | 2.82 | 14.51 |



| Readings | | | |
|-----------|-------|--------------------------|--|
| Reading # | MPa | Ignore | Notes |
| 1 | 6.16 | <input type="checkbox"/> | Rate 0.6 MPa/sec, Dur. 8.87 sec, Dolly 20 mm. |
| 2 | 4.23 | <input type="checkbox"/> | Rate 0.5 MPa/sec, Dur. 7.07 sec, Dolly 20 mm. |
| 3 | 7.09 | <input type="checkbox"/> | Rate 0.7 MPa/sec, Dur. 9.74 sec, Dolly 20 mm. |
| 4 | 7.61 | <input type="checkbox"/> | Rate 0.7 MPa/sec, Dur. 10.17 sec, Dolly 20 mm. |
| 5 | 5.81 | <input type="checkbox"/> | Rate 0.6 MPa/sec, Dur. 8.50 sec, Dolly 20 mm. |
| 6 | 4.03 | <input type="checkbox"/> | Rate 0.5 MPa/sec, Dur. 7.01 sec, Dolly 20 mm. |
| 7 | 8.26 | <input type="checkbox"/> | Rate 0.7 MPa/sec, Dur. 10.36 sec, Dolly 20 mm. |
| 8 | 10.14 | <input type="checkbox"/> | Rate 0.8 MPa/sec, Dur. 12.10 sec, Dolly 20 mm. |
| 9 | 5.36 | <input type="checkbox"/> | Rate 0.6 MPa/sec, Dur. 8.00 sec, Dolly 20 mm. |
| 10 | 6.05 | <input type="checkbox"/> | Rate 0.6 MPa/sec, Dur. 9.24 sec, Dolly 20 mm. |
| 11 | 5.60 | <input type="checkbox"/> | Rate 0.6 MPa/sec, Dur. 8.44 sec, Dolly 20 mm. |
| 12 | 6.93 | <input type="checkbox"/> | Rate 0.6 MPa/sec, Dur. 9.68 sec, Dolly 20 mm. |
| 13 | 7.80 | <input type="checkbox"/> | Rate 0.7 MPa/sec, Dur. 9.99 sec, Dolly 20 mm. |
| 14 | 10.95 | <input type="checkbox"/> | Rate 0.8 MPa/sec, Dur. 12.53 sec, Dolly 20 mm. |
| 15 | 5.41 | <input type="checkbox"/> | Rate 0.6 MPa/sec, Dur. 8.19 sec, Dolly 20 mm. |
| 16 | 5.76 | <input type="checkbox"/> | Rate 0.6 MPa/sec, Dur. 8.93 sec, Dolly 20 mm. |
| 17 | 4.98 | <input type="checkbox"/> | Rate 0.5 MPa/sec, Dur. 7.82 sec, Dolly 20 mm. |
| 18 | 7.72 | <input type="checkbox"/> | Rate 0.7 MPa/sec, Dur. 9.68 sec, Dolly 20 mm. |
| 19 | 3.19 | <input type="checkbox"/> | Rate 0.4 MPa/sec, Dur. 6.02 sec, Dolly 20 mm. |
| 20 | 4.67 | <input type="checkbox"/> | Rate 0.5 MPa/sec, Dur. 7.32 sec, Dolly 20 mm. |
| 21 | 11.38 | <input type="checkbox"/> | Rate 0.9 MPa/sec, Dur. 12.53 sec, Dolly 20 mm. |
| 22 | 10.98 | <input type="checkbox"/> | Rate 0.8 MPa/sec, Dur. 12.16 sec, Dolly 20 mm. |
| 23 | 8.31 | <input type="checkbox"/> | Rate 0.7 MPa/sec, Dur. 10.30 sec, Dolly 20 mm. |
| 24 | 10.01 | <input type="checkbox"/> | Rate 0.8 MPa/sec, Dur. 11.66 sec, Dolly 20 mm. |
| 25 | 9.51 | <input type="checkbox"/> | Rate 0.8 MPa/sec, Dur. 10.98 sec, Dolly 20 mm. |
| 26 | 10.52 | <input type="checkbox"/> | Rate 0.8 MPa/sec, Dur. 11.85 sec, Dolly 20 mm. |
| 27 | 7.17 | <input type="checkbox"/> | Rate 0.7 MPa/sec, Dur. 9.12 sec, Dolly 20 mm. |
| 28 | 3.48 | <input type="checkbox"/> | Rate 0.4 MPa/sec, Dur. 6.26 sec, Dolly 20 mm. |
| 29 | 4.00 | <input type="checkbox"/> | Rate 0.5 MPa/sec, Dur. 6.57 sec, Dolly 20 mm. |
| 30 | 4.42 | <input type="checkbox"/> | Rate 0.5 MPa/sec, Dur. 6.89 sec, Dolly 20 mm. |
| 31 | 7.70 | <input type="checkbox"/> | Rate 1.2 MPa/sec, Dur. 10.30 sec, Dolly 20 mm. |
| 32 | 5.32 | <input type="checkbox"/> | Rate 0.6 MPa/sec, Dur. 7.57 sec, Dolly 20 mm. |
| 33 | 5.52 | <input type="checkbox"/> | Rate 0.6 MPa/sec, Dur. 8.07 sec, Dolly 20 mm. |
| 34 | 5.72 | <input type="checkbox"/> | Rate 0.9 MPa/sec, Dur. 5.71 sec, Dolly 20 mm. |
| 35 | 7.57 | <input type="checkbox"/> | Rate 1.0 MPa/sec, Dur. 7.14 sec, Dolly 20 mm. |
| 36 | 7.26 | <input type="checkbox"/> | Rate 1.0 MPa/sec, Dur. 6.83 sec, Dolly 20 mm. |

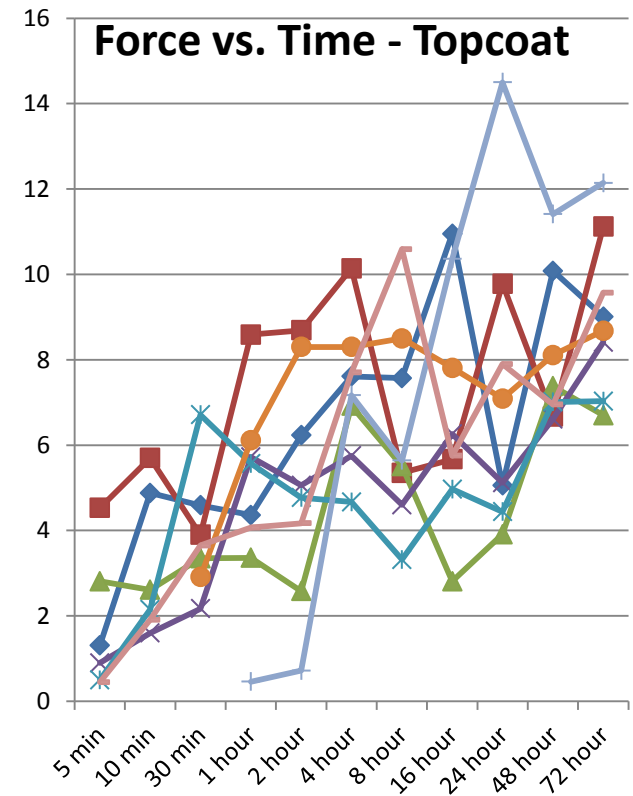
Results – Force vs Time

Steel



Paint

- ◆ Selleys QuickFIX Gel Supa glue
- Loctite 454 Instant Adhesive
- ▲ Selleys Araldite 90 Seconds
- ✕ Selleys Araldite 5 minute
- ✱ Loctite Ezy Repair 5 minute
- Selleys Araldite Ultra Clear
- ✦ Selleys Araldite Super Strength
- Loctite 4090 Hybrid Adhesive



Interpretation of Results

- The following is required to interpret the result
 - The force (MPa)
 - $F = m a$ (N)
 - $P = F / A$ (Pa or N/m^2) $\Rightarrow N/mm^2 = Mpa$
 - Evaluation on of both the dolly and test surface
 - Evaluation of the % of each failure

Results - Force

Steel

| Steel | Selleys QuickFIX Gel Supa glue | Loctite 454 Instant Adhesive | Selleys Araldite 90 Seconds | Selleys Araldite 5 minute | Loctite Ezy Repair 5 minute | Selleys Araldite Ultra Clear | Selleys Araldite Super Strength | Loctite 4090 Hybrid Adhesive |
|---------|--------------------------------|------------------------------|-----------------------------|---------------------------|-----------------------------|------------------------------|---------------------------------|------------------------------|
| 5 min | 0.715 | 3.89 | 2.28 | 0.5 | 0.475 | #DIV/0! | #DIV/0! | 0.435 |
| 10 min | 1.24 | 4.565 | 2.29 | 1.705 | 2.695 | #DIV/0! | #DIV/0! | 0.44 |
| 30 min | 4.5 | 4.68 | 2.615 | 1.46 | 6.1 | 2.09 | #DIV/0! | 0.8 |
| 1 hour | 4.355 | 5.315 | 2.98 | 5.705 | 8.14 | 4.4 | 0.46 | 3.675 |
| 2 hour | 4.205 | 5.24 | 4.13 | 8.44 | 5.77 | 8.465 | 0.43 | 2.5 |
| 4 hour | 5.19 | 4.92 | 5.705 | 9.365 | 6.34 | 10.885 | 9.755 | 3.735 |
| 8 hour | 5.415 | 8.185 | 4.94 | 8.645 | 3.835 | 10.355 | 10.62 | 10.66 |
| 16 hour | 3.8 | 5.89 | 6.025 | 5.225 | 4.62 | 7.57 | 7.42 | 5.165 |
| 24 hour | 3.88 | 6.16 | 7.18 | 6.455 | 5.325 | 8.34 | 11.525 | 7.25 |
| 48 hour | 4.32 | 6.96 | 6.84 | 5.895 | 3.98 | 8.635 | 9.125 | 11.39 |

Primer

| Prime | Selleys QuickFIX Gel Supa glue | Loctite 454 Instant Adhesive | Selleys Araldite 90 Seconds | Selleys Araldite 5 minute | Loctite Ezy Repair 5 minute | Selleys Araldite Ultra Clear | Selleys Araldite Super Strength | Loctite 4090 Hybrid Adhesive |
|---------|--------------------------------|------------------------------|-----------------------------|---------------------------|-----------------------------|------------------------------|---------------------------------|------------------------------|
| 5 min | 1.59 | 7.22 | 2.45 | 0.46 | 0.51 | | | 0.93 |
| 10 min | 2.56 | 5.46 | 1.35 | 1.04 | 2.9 | | | 0.45 |
| 30 min | 4.19 | 5.71 | 3.44 | 2.33 | 8.36 | 3.24 | | 2.32 |
| 1 hour | 2.23 | 7.35 | 3.15 | 6.53 | 4.56 | 6.52 | 0.46 | 3.65 |
| 2 hour | 3.12 | 7.17 | 3.68 | 6.57 | 4.48 | 10.28 | 0.57 | 1.97 |
| 4 hour | 7.03 | 8.25 | 5.59 | 5.41 | 3.1 | 10.97 | 10.52 | 4.41 |
| 8 hour | 5.71 | 7.83 | 4.5 | 5.97 | 4.21 | 10.36 | 5.88 | 7.39 |
| 16 hour | 5.81 | 4.77 | 5.18 | 5.91 | 3.96 | 5.71 | 7.48 | 5.19 |
| 24 hour | 6.5 | 4.56 | 6.47 | 5.29 | 4.76 | 5.67 | 7.59 | 6.12 |
| 48 hour | 7.1 | 7.66 | 8.39 | 6.66 | 4.86 | 6.46 | 6.93 | 8.05 |
| 72 hour | 6.43 | 7.88 | 6.3 | 6.47 | 3.97 | 4 | 7.59 | 8.17 |

Topcoat

| Top | Selleys QuickFIX Gel Supa glue | Loctite 454 Instant Adhesive | Selleys Araldite 90 Seconds | Selleys Araldite 5 minute | Loctite Ezy Repair 5 minute | Selleys Araldite Ultra Clear | Selleys Araldite Super Strength | Loctite 4090 Hybrid Adhesive |
|---------|--------------------------------|------------------------------|-----------------------------|---------------------------|-----------------------------|------------------------------|---------------------------------|------------------------------|
| 5 min | 1.31 | 4.53 | 2.81 | 0.9 | 0.5 | | | 0.45 |
| 10 min | 4.88 | 5.7 | 2.61 | 1.6 | 2.15 | | | 1.91 |
| 30 min | 4.59 | 3.9 | 3.35 | 2.17 | 6.71 | 2.91 | | 3.65 |
| 1 hour | 4.36 | 8.59 | 3.36 | 5.72 | 5.57 | 6.11 | 0.46 | 4.07 |
| 2 hour | 6.23 | 8.69 | 2.58 | 5.06 | 4.77 | 8.3 | 0.72 | 4.17 |
| 4 hour | 7.61 | 10.14 | 6.92 | 5.75 | 4.67 | 8.3 | 7.17 | 7.7 |
| 8 hour | 7.57 | 5.35 | 5.51 | 4.6 | 3.32 | 8.5 | 5.64 | 10.59 |
| 16 hour | 10.95 | 5.67 | 2.81 | 6.26 | 4.97 | 7.81 | 10.36 | 5.75 |
| 24 hour | 5.06 | 9.78 | 3.91 | 5.12 | 4.44 | 7.09 | 14.5 | 7.9 |
| 48 hour | 10.08 | 6.67 | 7.38 | 6.61 | 7.01 | 8.11 | 11.41 | 6.95 |
| 72 hour | 9.01 | 11.12 | 6.7 | 8.41 | 7.03 | 8.68 | 12.14 | 9.57 |

- Cyanoacrylate adhere well to coating
- Epoxy adhere well after 8 hours

Failure Evaluation

- Adhesion
 - when a coating fails at the interface with another layer (or substrate).
 - the dolly and test surface having different colours.
 - Reported as a % of the area and both the coatings (i.e. A/B).
- Cohesion
 - when a coating splits within itself.
 - This is identified by the dolly and test surface having the same colours.
 - Reported as a % of the area and the single coating affected (ie B).
- Glue Failure
 - where the glue fails
 - does not adhere to the coating or dolly,
 - or the glue fails cohesively (ie glue on each surface).
 - Reported as a % of the area

Results – Co. vs Adhesion

Steel

| Steel | Selleys QuickFIX | Loctite 454 | Selleys Araldite | Selleys Araldite | Loctite Ezy Repair | Selleys Araldite | Selleys Araldite | Loctite 4090 |
|---------|------------------|-------------|------------------|------------------|--------------------|------------------|------------------|--------------|
| 5 min | Adhesion | Adhesion | Adhesion | Cohesion | Cohesion | | | Cohesion |
| 5 min | Adhesion | Adhesion | Adhesion | Cohesion | Cohesion | | | Cohesion |
| 10 min | Adhesion | Adhesion | Cohesion | Cohesion | Cohesion | | | Adhesion |
| 10 min | Adhesion | Adhesion | Adhesion | Cohesion | Cohesion | | | Cohesion |
| 30 min | Adhesion | Adhesion | Adhesion | Cohesion | Cohesion | Cohesion | | Adhesion |
| 30 min | Adhesion | Adhesion | Adhesion | Cohesion | Cohesion | Cohesion | | Adhesion |
| 1 hour | Adhesion | Adhesion | Adhesion | Cohesion | Cohesion | Cohesion | Cohesion | Cohesion |
| 1 hour | Adhesion | Adhesion | Adhesion | Cohesion | Cohesion | Cohesion | Cohesion | Cohesion |
| 2 hour | Cohesion | Adhesion | Adhesion | Cohesion | Adhesion | Cohesion | Cohesion | Adhesion |
| 2 hour | Adhesion | Adhesion | Cohesion | Cohesion | Cohesion | Cohesion | Cohesion | Adhesion |
| 4 hour | Cohesion | Cohesion | Adhesion | Adhesion | Adhesion | Adhesion | Adhesion | Cohesion |
| 4 hour | adhesion | Cohesion | Adhesion | Adhesion | Adhesion | Cohesion | Cohesion | Cohesion |
| 8 hour | Adhesion | Cohesion | Adhesion | Cohesion | Cohesion | Adhesion | Cohesion | Cohesion |
| 8 hour | cohesion | Cohesion | Adhesion | Cohesion | Cohesion | Cohesion | Cohesion | Cohesion |
| 16 hour | Cohesion | cohesion | Adhesion | Adhesion | Cohesion | Cohesion | Adhesion | Adhesion |
| 16 hour | cohesion | cohesion | Cohesion | Adhesion | Adhesion | Cohesion | Cohesion | Cohesion |
| 24 hour | Cohesion | cohesion | Adhesion | Adhesion | Adhesion | Cohesion | Adhesion | Adhesion |
| 24 hour | | | | Adhesion | Cohesion | Cohesion | Cohesion | Cohesion |
| 48 hour | | | | Adhesion | Adhesion | Adhesion | Adhesion | Adhesion |
| 48 hour | cohesion | cohesion | adhesion | adhesion | Adhesion | Adhesion | Adhesion | Adhesion |
| 72 hour | cohesion | cohesion | Adhesion | Adhesion | Adhesion | Adhesion | Adhesion | Cohesion |
| 72 hour | | | | Adhesion | Adhesion | Adhesion | Adhesion | |

Primer

| Primer | Selleys QuickFIX Gel Supa glue | Loctite 454 Instant Adhesive | Selleys Araldite 90 Seconds | Selleys Araldite 5 minute | Loctite Ezy Repair 5 minute | Selleys Araldite Ultra Clear | Selleys Araldite Super Strength | Loctite 4090 Hybrid Adhesive |
|---------|--------------------------------|------------------------------|-----------------------------|---------------------------|-----------------------------|------------------------------|---------------------------------|------------------------------|
| 5 min | Cohesion | Cohesion | Adhesion | Cohesion | Cohesion | | | Cohesion |
| 10 min | Adhesion | Cohesion | Cohesion | Cohesion | Cohesion | | | Cohesion |
| 30 min | Adhesion | Adhesion | Adhesion | Cohesion | Cohesion | Cohesion | | Cohesion |
| 1 hour | Adhesion | Cohesion | Adhesion | Adhesion | Adhesion | Cohesion | Cohesion | Cohesion |
| 2 hour | Cohesion | Cohesion | Adhesion | Adhesion | Adhesion | Cohesion | Cohesion | Adhesion |
| 4 hour | Adhesion | Cohesion | Adhesion | Adhesion | adhesion | Adhesion | Cohesion | Adhesion |
| 8 hour | Cohesion | Cohesion | Adhesion | Adhesion | Cohesion | Adhesion | Cohesion | Adhesion |
| 16 hour | Cohesion | cohesion | Adhesion | Adhesion | Adhesion | Adhesion | Cohesion | Adhesion |
| 24 hour | Adhesion | cohesion | Adhesion | Adhesion | Adhesion | Adhesion | Cohesion | Adhesion |
| 48 hour | adhesion | adhesion | adhesion | Adhesion | Adhesion | Adhesion | Adhesion | Adhesion |
| 72 hour | adhesion | adhesion | Adhesion | Adhesion | Adhesion | Adhesion | Cohesion | Adhesion |

Topcoat

| Topcoat | Selleys QuickFIX Gel Supa glue | Loctite 454 Instant Adhesive | Selleys Araldite 90 Seconds | Selleys Araldite 5 minute | Loctite Ezy Repair 5 minute | Selleys Araldite Ultra Clear | Selleys Araldite Super Strength | Loctite 4090 Hybrid Adhesive |
|---------|--------------------------------|------------------------------|-----------------------------|---------------------------|-----------------------------|------------------------------|---------------------------------|------------------------------|
| 5 min | Cohesion | Adhesion | Adhesion | Cohesion | Cohesion | | | Cohesion |
| 10 min | Adhesion | Adhesion | Adhesion | Cohesion | Adhesion | | | Adhesion |
| 30 min | Adhesion | Adhesion | Adhesion | Cohesion | Cohesion | Cohesion | | Cohesion |
| 1 hour | Adhesion | Adhesion | Adhesion | Adhesion | Adhesion | Adhesion | Cohesion | Cohesion |
| 2 hour | Cohesion | Adhesion | Adhesion | Adhesion | Adhesion | Cohesion | Adhesion | Adhesion |
| 4 hour | Cohesion | Cohesion | Adhesion | Adhesion | adhesion | Adhesion | Cohesion | Cohesion |
| 8 hour | Adhesion | Cohesion | Adhesion | Adhesion | Adhesion | Adhesion | Adhesion | Adhesion |
| 16 hour | Adhesion | cohesion | Cohesion | Adhesion | Adhesion | Adhesion | test fail - | Cohesion |
| 24 hour | test failed | Adhesion | Adhesion | Adhesion | Adhesion | Adhesion | Adhesion | Adhesion |
| 48 hour | adhesion | adhesion | Adhesion | Adhesion | Adhesion | Adhesion | Adhesion | Adhesion |
| 72 hour | adhesion | Adhesion | Adhesion | Adhesion | Adhesion | Adhesion | Adhesion | Cohesion |

- Cyanoacrylate adhesion to cohesion
- Epoxy cohesive to adhesive

Results – Failure Location

Steel

| Steel | Selleys QuickFIX | Loctite 454 | Selleys Araldite | Selleys Araldite | Loctite Ezy Repair | Selleys Araldite | Selleys Araldite | Loctite 4090 |
|---------|------------------|-------------|------------------|------------------|--------------------|------------------|------------------|--------------|
| 5 min | Glue to dd | Glue to dd | glue to su | Glue | Glue | | | Glue |
| 5 min | Glue to dd | Glue to dd | glue to su | Glue | Glue | | | Glue |
| 10 min | Glue to dd | Glue to dd | Glue | Glue | Glue | | | Glue to do |
| 10 min | Glue to dd | Glue to dd | Glue to dd | Glue | Glue | | | Glue |
| 30 min | Glue to dd | Glue to dd | Glue to dd | Glue | Glue | Glue | | Glue to do |
| 30 min | Glue to dd | Glue to dd | Glue to dd | Glue | Glue | Glue | | Glue to do |
| 1 hour | Glue to dd | Glue to dd | Glue to dd | Glue | Glue | Glue | Glue | Glue |
| 1 hour | Glue to dd | Glue to dd | Glue to dd | Glue | Glue | Glue | Glue | Glue |
| 2 hour | Glue | Glue to dd | Glue to dd | glue | Glue to dd | Glue | Glue | Glue to do |
| 2 hour | Glue to dd | Glue to dd | Glue | glue | Glue | Glue | Glue | Glue to do |
| 4 hour | Glue | Glue | Glue to dd | glue to do | Glue | Glue | glue | glue |
| 4 hour | Glue to dd | Glue | Glue to dd | glue to do | Glue to dd | glue | glue | glue |
| 8 hour | Glue to dolly | | glue to do | glue | glue | glue to do | glue | glue |
| 8 hour | glue | Glue | glue to do | glue | glue | Glue | glue | glue |
| 16 hour | glue | glue | glue to do | glue to do | glue | glue | Glue to do | glue |
| 16 hour | glue | glue | glue | glue to do | glue | glue | glue | glue |
| 24 hour | glue | glue | glue to do | glue to su | Glue to do | glue | glue | glue to su |
| 24 hour | | | | glue to do | glue | glue | glue | glue |
| 48 hour | | | | glue to su | glue to do | glue to su | glue to su | glue to su |
| 48 hour | glue | glue | glue to su | glue to do | Glue to do | glue to su | ue to sub | glue to su |
| 72 hour | glue to do | glue to do | glue to su | glue to do | glue to su | 40% glue | glue to su | Glue |
| 72 hour | | | | | glue to su | 50% glue | glue to su | Glue to do |

- Steel
 - Cyanoacrylate
 - early adhesion to dolly
 - Late glue cohesion
 - Epoxy
 - Early Glue Cohesion
 - Glue to paint
- Paint
 - Cyanoacrylate
 - early adhesion to dolly
 - Late paint film failure
 - Epoxy
 - Early Glue Cohesion
 - Middle Glue to dolly
 - Late Glue to paint

Primer

| Primer | Selleys QuickFIX Gel Supa glue | Loctite 454 Instant Adhesive | Selleys Araldite 90 Seconds | Selleys Araldite 5 minute | Loctite Ezy Repair 5 minute | Selleys Araldite Ultra Clear | Selleys Araldite Super Strength | Loctite 4090 Hybrid Adhesive |
|---------|--------------------------------|------------------------------|-----------------------------|---------------------------|-----------------------------|------------------------------|---------------------------------|------------------------------|
| 5 min | Glue | Paint | Glue to p | Glue | Glue | | | Glue |
| 10 min | Glue to do | Paint | Glue | Glue | Glue | | | Glue |
| 30 min | Glue to do | Glue to do | Glue to p | Glue | Glue | Glue | | Glue |
| 1 hour | Glue to do | Glue | Glue to p | Glue to p | Glue to p | Glue | Glue | Glue |
| 2 hour | Glue | coating | Glue to do | glue to do | Glue to do | Glue | Glue | Glue to do |
| 4 hour | coating to | Primer | Glue to do | glue to do | Glue to do | Glue | primer | glue to do |
| 8 hour | Primer | Primer | glue to do | glue to do | glue | glue to do | primer | glue to do |
| 16 hour | primer | 90% glue | glue to do | glue to do | Glue to do | glue to p | primer | Glue to do |
| 24 hour | primer | glue | glue to do | Glue to p | Glue to p | Glue to p | Glue to p | Glue to p |
| 48 hour | primer to | primer to | Glue to p | Glue to p | glue to do | primer to | Glue to p | 10% to sub |
| 72 hour | primer to | primer to | 0 | Glue to p | Glue to p | Glue to p | primer | Glue to do |

Topcoat

| Topcoat | Selleys QuickFIX Gel Supa glue | Loctite 454 Instant Adhesive | Selleys Araldite 90 Seconds | Selleys Araldite 5 minute | Loctite Ezy Repair 5 minute | Selleys Araldite Ultra Clear | Selleys Araldite Super Strength | Loctite 4090 Hybrid Adhesive |
|---------|--------------------------------|------------------------------|-----------------------------|---------------------------|-----------------------------|------------------------------|---------------------------------|------------------------------|
| 5 min | Glue | Glue to do | Glue to do | Glue | Glue | | | Glue |
| 10 min | Glue to do | Glue to do | Glue to p | Glue | Glue to p | | | Glue to do |
| 30 min | Glue to do | Glue to do | Glue to do | Glue | Glue | Glue | | Glue |
| 1 hour | Primer to | Primer to | Glue to p | Glue to p | Glue to p | Glue to p | Glue | Glue |
| 2 hour | Glue | Glue to do | Glue to do | glue to do | Glue to do | Glue | Glue to do | Glue to do |
| 4 hour | primer | Primer | Glue to do | glue to do | Glue to do | Glue | primer | glue |
| 8 hour | topcoat to | Glue | glue to do | glue to do | glue to do | glue to do | Glue to do | glue to do |
| 16 hour | topcoat to | glue to do | glue | glue to do | Glue to do | glue to do | topcoat | Glue to p |
| 24 hour | dolly rem | topcoat to | glue to do | Glue to p | Glue to p | 1% topcoa | topcoat to | Glue to p |
| 48 hour | topcoat to | glue to do | Glue to p | Glue to p | Glue to p | Glue to p | topcoat to | Glue to p |
| 72 hour | topcoat to | topcoat to | Glue to p | Glue to p | Glue to p | Glue to p | topcoat to | glue |

Budget vs. Costs

| Item | Budget | Actual |
|----------------|--------------------|----------------------|
| Panels | \$200 | \$800 |
| Dollies | \$200 | \$825 |
| Adhesive | \$100 | \$263 |
| Abrasive paper | \$20 | \$28 |
| Prep | 1 hour | 4 hours |
| Glueing | 2 hours | 5 hours |
| Pulling | 4 hours | 20 hours |
| TOTAL | \$ 520 and 8 hours | \$ 2000 and 30 hours |

Conclusions

- Steady increase of force vs. time (graph)
- Blasted substrate will allow for higher adhesion
- Low cost practical paper with usable results
- No outstanding winners

Conclusions

- Hard to compare cure and strength by the packets
- Cost of glue is not proportional to adhesion
- Adhesion to blasted steel was not higher than painted
- Quick curing one-part cyanoacrylates (super glues) may be sufficient on smooth coatings
- Two-part epoxies are preferred for porous or rough coatings

Advice

- Always conduct several test in a location
- Always test several representative sites on coating system
- On vertical surfaces only use cloth tape to hold in position
- Location of failure is important look at both faces (dolly and substrate)
- A 10x magnifying glass is helpful

Challenges

- Challenges
 - Difficult to time gluing
 - Difficult to apply 100 microns of glue
 - Pulling one dolly takes 60 to 90 seconds
 - Having enough data to be statistically significant
- Future work
 - Select 3-4 adhesives for additional testing in the 3-8 hour region
 - Temperature effects
 - Try different abrasives on dolly?



Questions?

I'll Be Back!

Thanks to Alex Shepherd, Dave Mavros and Nadia Manzelli