

## Using ASTM Method C297, Flatwise Tensile Strength, as an Indicator of Resin Acrylic-Bonding-Potential for Tub and Shower Laminates.

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### Abstract

Determining a resin's bonding potential to an acrylic or ABS substrate is critical to a resin manufacturer that supplies the tub and shower industry. Although tub and shower manufacturers have different procedures for testing bonding, these tests are not standardized and the results are largely open to interpretation. ASTM Method C297 is a valuable tool as it is standardized, repeatable, and gives quantifiable data. This paper covers the method in detail, how to apply the method to tub and shower laminates, and why the data can be helpful in predicting how a resin will perform under real production conditions.

### Introduction

The bonding potential of a resin to acrylic and ABS substrates is the critical factor in determining if a resin is appropriate to use for bulk backup of an acrylic or ABS tub shower line. If the resin does not bond properly to the substrates, the result is delamination, costly repair, or outright scraping of the effected units. Even worse if delamination problems are not detected during trimming or elsewhere on the production line, the effected units can make it all the way to the final customer. This can then affect their overall impression of the tub manufacturer and can be associated with very costly claims and fines. This is why it is essential that bonding be evaluated before the units leave the manufacturer's plant.

Most manufacturers have their own internal testing procedures to test for bonding. Checking for delamination during trimming is the most common and simplest way to check for bonding problems. Other methods include testing the drain cutouts for adhesion. This can be done simply by throwing or hurling the cutout on the shop floor. If the substrate "pops off", or debonds easily then bonding problem will most likely surface in the units. Another common bonding test uses a screwdriver to wedge in between the laminate and substrate. This can be done by using the drain cut outs or

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the tub itself and testing the ease of in which the laminate can be separated from the substrate. If the debonded area shows little or no residue or glass fibers on the substrate, this can be an indication of debonding problems.

Although all of these different testing methods can be useful in their own right, there are limitations to all of them. All are open to varying degrees of interpretation. Two individuals can have a different view of what constitutes proper bonding. Drain cutouts can have differing results, and the results of hurling or throwing the cut out on to the floor can vary depending on how the laminate impacts the floor, or how it is pulled apart. All of these methods are limited by the fact that they are not controlled, not standardized, and open to the interpretation of the tester. By applying the use of ASTM Method C297, Flatwise Tensile Strength, to tub and shower laminates; some of these limitations can be alleviated.

### ASTM Method C297

ASTM Method C297 is designed to test the bonding of sandwich panels. The basics of this method are as follows. The sample is subjected to a tensile load normal to the plane of the sample. The samples are bonded to the loading blocks using an adhesive, and loading blocks placed in the testing machine. The machine then applies a tensile load to the blocks and records the ultimate load placed upon the sample. Samples are run in at least duplicates of five. Flatwise tensile strength is calculated as follows:

$$\sigma = P/A \quad (1)$$

where:

$\sigma$  = Flatwise tensile strength, MPa (psi)

P = ultimate load, N (lb)

A = cross-sectional area of the sample, mm<sup>2</sup> (in<sup>2</sup>)

The method described above is the standard ASTM method. The basics of this method can be easily applied to testing acrylic and ABS reinforced tub and shower laminates, with a few additions and changes.

### Sample preparations

The samples used for testing may be samples that were laminated by hand, but ideally would be pieces from a tub off the actual production line of a manufacturer. In either case it is of vital importance that the samples be relatively flat and free of large visible flaws and imperfections. The sample laminate is cut into 1 by 1 inch square specimens, using a wet saw, as seen in Fig.1. It is recommended that 10 specimens be run in duplicate, to insure a good impression of the overall bonding. Fig.2 shows the 10 specimens cut from a sample from a tub unit. The specimens may need to be

smoothed out in order to fit smooth with the loading blocks. This is done by sanding the laminate side of the specimen until it can fit flat with the loading block. Once the specimens are cut and sanded, they must be bonded to the loading blocks. Fig.3 shows the specimen and loading blocks ready to be bonded. Use just enough adhesive to insure a complete surface to surface bond between the loading block and sample, as seen in Fig.4 Proper bonding of the samples to the loading blocks is critical to ensuring accurate data. The blocks must be secured using an adhesive or glue that has bond strength greater than the potential bond strength of the laminate being tested (typical adhesive or glue strength ~1800-2400 psi). In order to test this bond strength a test should be run by gluing two loading blocks together without the sample in between, as seen is Fig.5. Testing this sample will give a base line value for the adhesive bond strength. If the results of the adhesive bond strength test are not above the minimum required for testing acrylic and ABS substrates, then a fresh batch or different type of adhesive should be used. It must also be assured that the adhesive curing temperature be low enough as to not effect the specimens to be tested.

## Sample Conditioning

Once the specimens are bonded to the loading block, proper conditioning must be followed before testing. The loading block assembly should be allowed to set for 24 hours before testing. The assembly should not be subjected to temperatures outside the range of  $23\pm 3^{\circ}\text{C}$ , and relative humidity's ranging from  $50\pm 5\%$ . The physical properties of the specimens may be affected if the test specimens are not brought to constant weight ( $\pm 1\%$ ) before testing.

## Testing

An accurate measurement of the exact size of each specimen is needed as the cross-sectional area of the specimen is necessary to calculate the Flatwise tensile strength. Before placing in testing machine, measure and record the planar dimensions and thickness of each specimen, as seen in Fig.6. The test machine must be capable of maintaining a controlled loading rate and measuring the load with an accuracy of  $\pm 1\%$  of the indicated value. The loading blocks must be self-aligning and must be sufficiently stiff to ensure the bonded facings remain flat under load. Fig.7 shows the testing machine with the specimen properly secured for testing. When the loading blocks have been secured in the setup, the machine then applies a tensile load to the blocks at a rate of 0.020 in/min. This should ensure that the ultimate load will occur between three to six minutes.

## Types of Failure

The ultimate load recorded by the machine at the moment before the specimen breaks or fails, is the key factor in determining the Flatwise tensile strength of a laminate. However it is just as important to see the type of failure that has occurred. The type of failure can determine how meaningful the resulting number is, or if it is relevant or not. There are four types of failure:

Two types are related to the failure of the specimen or sample being tested.

Laminate or Core failure: Fig.8: This type of failure occurs in the laminate or core side of the specimen (i.e. the laminate is ripped apart.) It can be noted that resin residue or glass fibers of the laminate are in the facing (substrate) or in the adhesive (glue) that bonds the laminate or core to the block. In certain cases it may just be resin residue as opposed to glass fibers.

Substrate or Facing failure: Fig.9: This type of failure occurs in the substrate (in case of tubs, acrylic or ABS) side of the specimen, or in the bond between the substrate and laminate. In this type of failure the substrate has ripped apart and the interface between the substrate and laminate has broken. This shows a weakness in the laminate to substrate bond, especially if both seem to be intact and the surface between them is clean and smooth. It should be noted that this type of failure is an indication of potential bonding problems, especially if this type of failure is consistent on other specimens. This type of failure is what one would not want to see.

The other two types of failure are related to the adhesive used to glue the loading blocks to the specimens. These types of failure are termed "Adhesion" failure of glue (adhesive) and "Cohesive" failure of glue (adhesive). This type of failure is not common as the glue (adhesive) strength will typically be greater than the bond strength of the samples being tested. In some cases the failure could be caused due to improper application of the glue (adhesive) to either the laminate or substrate side and the loading blocks. Hence it is very important to ensure during specimen preparation that the glue is well set on to the loading blocks and specimen before start of test with minimal voids. The data for a specimen that fails in the adhesive (glue) is not necessarily bad data, since the interface between the laminate and substrate is intact. It would be suggested to retest with additional specimens.

Adhesion Failure of Glue (Adhesive): This type of failure is by debonding of the adhesive to the loading block or laminate specimen. In this type of failure the adhesive debonds cleanly from either the specimen of the loading block, but the corresponding side of the specimen or loading block is smooth and with very little

adhesive residue. In the case of this type of failure, the data obtained for bond strength to determine how well a laminate bonded to the substrate is not a good indication since the interface between the facing (substrate) and the laminate (core) is still intact. It would be suggested to retest with additional specimens.

Cohesive failure of Glue (Adhesive): Fig.10: This type of failure occurs when the adhesive is ripped apart. Pieces and residue of the adhesive can be seen on both the loading block and/or specimen. Since the failure is in the adhesive and not in the specimen, this type of failure does not constitute a poor bond since the interface between the facing (substrate) and the laminate (core) is still intact. It would be suggested to retest with additional specimens.

## Results and Report

The report from this testing should include: Descriptions and dimensions of the test specimens: including the samples organization, be it from a manufactures production floor or laminated by hand. The conditioning of the specimens: including the adhesive used and conditioning temperatures. Also the testing machine and cross-head loading rate. Most importantly the report must include the Flatwise tensile strength and the type of failure seen for each specimen.

The flatwise tensile strength gives a number which represents the highest force load per inch that the specimen was able to withstand just before failure. This is the weakest link in the sample be it the laminate, the substrate, or the bond between the two. If the type of failure is in the laminate, it can be assumed that the bond between the two is at least as strong as the flatwise tensile strength recorded for the sample. If the failure is in the substrate, then flatwise tensile strength value give an even closer representation of the bonding strength between the laminate and substrate. However it is unlikely that each specimen from any sample will fail in the same manner. This is why it is important to test ten specimens. Some may fail in the adhesive, laminate or adhesive. Others may have statistically high or low flatwise tensile strength values and not give a good representation of the bonding of the whole sample. It is important to look at both flatwise tensile adhesion strength (psi) and type of failure when trying to determine how a resin will perform in the field.

## Data and Interpretation

Using the old standby “screwdriver test”, a bond between a laminate and substrate can be evaluated using three categories:

Gluing Effect: How well does the laminate “glue” to the substrate. The relative amount of force needed to pull the laminate from the substrate.

Etching Effect: How well does the laminate etch or “eat” into the substrate. Etching can be seen as resin residue, imprints, defacements, or any other “damage” done to the substrate as a result of the bond being pulled apart.

Fiber Tear: How much fiber remains on the substrate after debonding. This is what most manufacturers like to see, as this generally means the bond is strong enough so the laminate literally rips apart before the bond separates from the substrate.

Normally any resin used for laminate will have some aspect of Gluing Effect. Although Gluing Effect is important as it represents the initial force needed to debond a laminate, but gluing effect itself is not enough to conclusively say that bonding problems will not arise. A resin that shows some Etching Effect will generally have more resistance to a continued debonding, after the initial separation then a resin that shows only Gluing Effect. Fiber Tear is simply a continuation of a good Etching and Gluing Effect. In the case of Fiber Tear the resin has etched in well enough and the Gluing Effect is strong enough to cause the laminate to rip apart before debonding from the substrate.

When interpreting the data (see Table 1) one must take into account the Flatwise tensile strength value, and the type of failure. First consider the Flatwise tensile strength value by itself. This value gives a good representation of the “Gluing Effect” of the bond. This is useful as it is a quantifiable number instead of a qualitative analysis that is normally open to the interpretation of the tester. If the average of the specimens is below 1000psi, this is the first indication that bonding may be a concern. A standard deviation of a set of samples should be normally be no greater than 250. A standard deviation of more then this shows a high level of inconsistency in the sample. In this case, the sample should be retested.

To better understand how Etching effect and Fiber Tear can be related to the flatwise tensile strength testing, the percentage of each type of failure should be calculated from the results of each specimen. The most common type of failure is Laminate failure. If results show a large percentage of Substrate (facing) failure this is an indication of poor bonding potential. Especially if this is seen with “low” flatwise tensile strength numbers. Flatwise tensile strength will vary depending on the strength of the laminate. In the case of a laminate failure, the bond between the substrate and the laminate can be assumed to be at least as strong as the force need to pull the laminate apart.

The advantages of using the flatwise tensile strength over the “screwdriver test” are: flatwise tensile strength testing gives a quantifiable number that relates closely to the “Gluing Effect” of the “screwdriver test”. Although there are variables to this test such as method of application of the glue or adhesive to the loading blocks and laminate, or method of application of the laminate to the substrate, voids and controlled temperature, humidity conditions, this test method is repeatable provided the variables are kept to a minimum.

The data from Table 1 can be interpreted as follows:

**Note 1:** The C297 method for sample A yielded a fairly high value of tensile adhesion strength. Based on the type of failure, which is basically "laminar" failure, one would expect that the field testing of actual tubs should be very good. This was confirmed with the Production floor testing using the "Screwdriver" method of actual drain cut outs from acrylic tub. There was very good fiber tear and gluing effect upon inspection.

**Note 2:** The tensile adhesion strength for sample B was quite high, but the type of failure showed that there was more adhesive failure of the glue to the loading blocks and laminate than in the laminate itself. Based on this type of failure, which includes both laminar and adhesive failure and the tensile adhesion strength was high; one would expect that the field testing to be good, but not the best. It is important to note that facing failure is what one needs to be concerned about since the interface between the substrate and laminate is broken with this failure. The adhesive failure during lab testing could be due to improper application of the glue or adhesive to the loading blocks and laminate or voids present in them. Actual field testing showed there was decent amount of fiber tear and gluing effect upon inspection of the drain cut outs using screwdriver method.

**Note 3:** The tensile adhesion strength for lab testing of sample C and the standard deviation was quite high. If the standard deviation is greater than 250 psi, the specimens will have to be retested. The type of failure was predominantly laminar failure which one would expect that for field testing due to the high standard deviation one might expect fair results but will be inconsistent. This was confirmed with inconsistent data during field testing. There were cut outs which had mixed results with the amount of fiber tear and gluing effect. This shows that one will have high values for tensile adhesion strength and good failure types but if the standard deviation is high for the testing, one might see inconsistent results in the field.

**Note 4:** In the case of sample D, the tensile adhesion strength was low and the standard deviation

was high. If the standard deviation is greater than 250 psi, the specimens will have to be retested. The type of failure was predominantly laminar failure which one would expect that for field testing due to the high standard deviation and lower tensile adhesion strength values one might expect fair results that will be inconsistent. This was confirmed with inconsistent data during field testing. There were cut outs which had mixed results with the amount of fiber tear and gluing effect.

**Note 5:** In the case of sample E, the tensile adhesion strength was high and the standard deviation was slightly high. The type of failure was predominantly laminar failure but there was a fair amount of facing (substrate) failure. One would expect that for field testing we would have poor or inconsistent results due to the slightly high standard deviation and facing (substrate) type of failure. Actual field testing of drain cut outs showed there was poor fiber tear with fair amount of gluing effect. Most tub manufacturers would classify this as a poor bonding.

### Conclusions:

The results of the flatwise tensile adhesion test gives tub manufacturers an alternative to testing a potential resin for their application prior to actual field trials and a way to quantify bonding potential of the resin to the acrylic substrate as opposed to qualitative analysis such as the “screwdriver test”. The advantages of using the flatwise tensile strength over the “screwdriver test” are: flatwise tensile strength testing gives a quantifiable number that relates closely to the “Gluing Effect” of the “screwdriver test”. Although there are variables to this test such as method of application of the glue or adhesive to the loading blocks and laminate, or method of application of the laminate to the substrate, voids and controlled temperature, humidity conditions, this test method is repeatable provided the variables are kept to a minimum.

Both of the following indicators are important to evaluate or correlate the ASTM C297 method to actual field trials: 1. Tensile adhesion strength (psi) 2. Type of failure (Laminar, Facing and Adhesive)

1. High values for tensile adhesion strength (1000 psi or more) with minimal standard deviation (no more than 250 psi) should typically yield good results in the field.

2. Caution has to be taken if the type of failure occurred during lab testing is in the “Substrate or Facing” i.e. the interface between laminar and substrate

3. Laminar failure is what is more typical of a good field result possibly combined with Adhesive failure.

4. Adhesive failure could indicate improper application of the glue or adhesive to the loading blocks and laminate. Note that since the interface between the laminar and substrate is still intact, this result does not constitute poor bonding of the laminar to the substrate

or acrylic. It shows there might have been some error during the sample preparation. If after two repetitions similar results occur, bonding is acceptable.



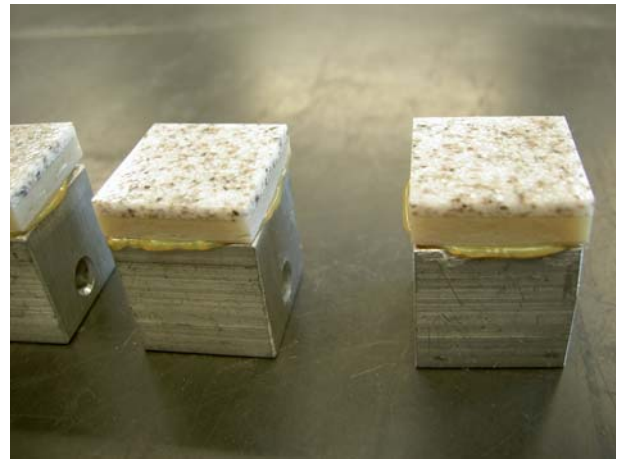
**Figure - 1: Cutting a sample on the wet saw.**



**Figure - 2: Ten specimens before sanding.**



**Figure - 3: A specimen and the two loading blocks ready to be bonded.**



**Figure - 4: One side of the specimen glued to one block.**



**Figure - 5: Two loading blocks glued together to test glue bond strength.**



**Figure - 6:** measuring the specimen before testing.



**Figure - 7:** A specimen loaded in the testing machine.



**Figure - 8: Laminate or Core Failure.** % Failure Type: Laminate = 100%, Facing = 0%, Adhesive = 0%



**Figure - 9: Substrate or Facing Failure.** % Failure Type: Laminate = 68%, Facing = 32%, Adhesive = 0%



**Figure - 10: Glue Failure: *In this case Cohesive Failure.*** % Failure Type: Laminate = 5%, Facing = 0%, Adhesive = 95%



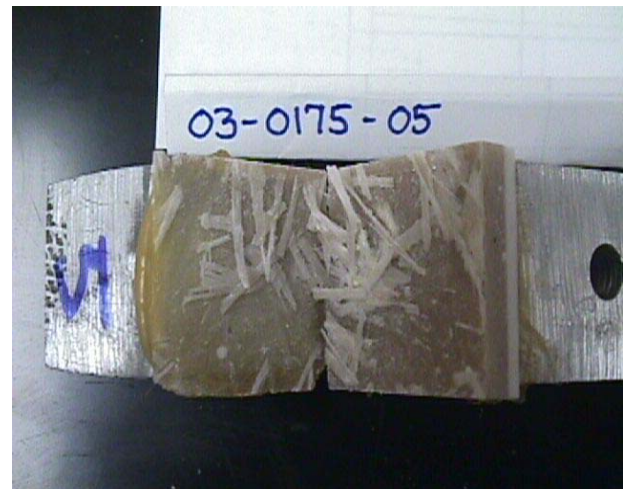
**Figure - 11: Substrate or Facing Failure: % Failure**  
 Type: Laminate = 40%, Facing = 60%, Adhesive = 0%



**Figure - 13: Adhesive or Glue Failure: % Failure**  
 Type: Laminate = 5%, Facing = 0%, Adhesive = 95%



**Figure - 12: Substrate or Facing Failure: % Failure**  
 Type: Laminate = 0%, Facing = 100%, Adhesive = 0%



**Figure - 14: Adhesive or Glue Failure: % Failure**  
 Type: Laminate = 25%, Facing = 0%, Adhesive = 75%

**Table - 1:** Qualitative and Quantitative Interpretation of Lab testing vs. Production Floor data

			Sample A	Sample B	Sample C	Sample D	Sample E
<b>ASTM Method C297 - Tensile Adhesion Data</b>	<b>Tensile Adhesion</b>	<b>psi</b>	<b>1,485.1</b>	<b>1,634.0</b>	<b>1,408.2</b>	<b>1,031.0</b>	<b>1,365.1</b>
	Strength	Std. Dev.	56.2	82.5	<b>245.1</b>	<b>241.3</b>	<b>156.2</b>
	Tensile Adhesion	kpsi	52.6	50.6	51.1	42.4	52.3
	Modulus	Std. Dev.	2.6	2.0	2.0	10.2	3.3
	<b>Failure of Facing</b>	<b>% (Mean)</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>0.0</b>	<b>32.0</b>
	<b>Failure of Laminate</b>	<b>% (Mean)</b>	<b>99.4</b>	<b>40.0</b>	<b>84.0</b>	<b>41.0</b>	<b>68.0</b>
	<b>Failure of Adhesive</b>	<b>% (Mean)</b>	<b>0.6</b>	<b>60.0</b>	<b>16.0</b>	<b>59.0</b>	<b>0.0</b>
<b>Production Floor Testing "Screwdriver" method of drain cut outs</b>	% Fiber Tear	% (Mean)	85.0	80.0	45.0	95.0	10.0
	% Gluing Effect	% (Mean)	65.0	85.0	50.0	60.0	45.0
	<b>% Overall Bonding</b>	<b>% (Mean)</b>	<b>75.0</b>	<b>82.5</b>	<b>47.5</b>	<b>77.5</b>	<b>27.5</b>
<b>Data Interpretation</b>	ASTM C297 method	-	Excellent	Good	Fair	Poor-Fair	Poor-Fair
	Production Floor	-	Good	Excellent	Fair	Fair	Poor
	<b>% Overall Bonding</b>	<b>PASS / FAIL</b>	<b>PASS (Note 1)</b>	<b>PASS (Note 2)</b>	<b>PASS with caution (Note 3)</b>	<b>FAIL (Note 4)</b>	<b>FAIL (Note 5)</b>