Tape Casting

Tape casting is a method of forming used throughout many different industries. In ceramics, tape casting is used to produce thin, flat substrates which serve as the base on which electronic circuits are printed.

The principle is as follows…

Ceramic powder is mixed in a matrix of binder and plasticizer. The binder acts as a glue, giving the matrix its strength. The plasticizer gives the matrix its plasticity. After thorough mixing, the mixture is spread thin on a flexible Mylar sheet. The thickness of this application must be as consistent as possible to reduce defects in the final tape. The mylar is pre-coated with silicon to encourage separation of mylar and tape. After curing (drying), the mylar and tape can be rolled up and stored for latter use.

When ready for use, the ceramic tape is separated fro the mylar backing. It can then be cut using exacto blades, shears, hole punchers etc. Multiple layers are often laminated into one object by moistening the layer-faces of tape using a solvent that is compatible with the binder and applying pressure.

Careful consideration must be given to the firing schedule in order to allow the binder and plasticizer will burn out completely. A rate of 50 F up to 500 F is generally acceptable for this. The top temperature is dictated by the ceramic being produced.

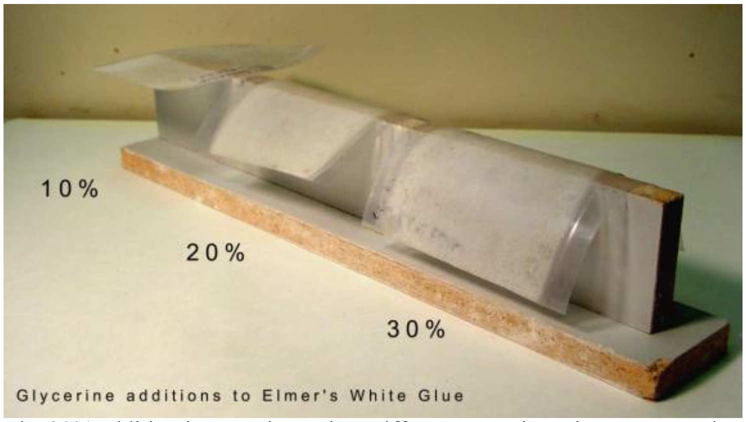
The beauty of tape casting is that its forming properties are independent of the ceramic component. The forming properties are a result of the binder and plasticizer. This means we can build using any combination of ceramic powders we want (including materials that are not plastic on their own). Glaze, slip, over-glaze, enamel, clay and single raw materials can now be exploited as building materials. They can be layered over pre-fired ceramics (i.e. as an over-glaze). Multiple layers of different colored tapes can be interwoven and fired as one… the possibilities are endless.

The Matrix

We will be using Elmer’s White Glue as our binder. Elmer’s contains a chemical called Polyvinyl Acetate, which is commonly used in the tape casting industry (industry uses a more concentrated version of PVA). It is safe, cleans up with water, and is readily available. We could make tape with just Elmer’s glue but there are a couple of problems with this approach… Elmer’s has a high amount of water and shrinkage. With only Elmer’s as our matrix, we end up with extreme warping as the mixture dries. This will literally buckle and lift our Mylar substrate off the table as it dries (even when the Mylar is glued down!). More importantly, Elmer’s dries rock hard. PVA is like a glass in that it is a liquid that is frozen at room temperature. If we raise its temperature, it begins to soften and turns from a solid to a semi-liquid (rub a piece of dried Elmer’s between your fingers and it will become more and more flexible).

Additions of Glycerin lower the temperature at which the transition from solid to liquid takes place. So Elmer’s is a solid at room temperature. By adding Glycerin, we are fooling Elmer’s into thinking that room temperature is much hotter than it actually is. Glycerin acts as a flux at room temperature. It tames Elmer’s hardness, giving it plasticity and a rubber-like feel.

A line blend was done between Elmer’s and Glycerin to determine which ratio works best. Strength is compromised with too little or too much Glycerin. Not enough Glycerin creates a matrix which is not rubbery enough. It cracks when peeled from the Mylar because it lacks plasticity. Too much Glycerin reduces strength, and the coating rips as it is seprated from the Mylar. We found that a ratio of 80% Elmer’s to 20% Glycerin creates a good combination of plasticity and strength. The image below shows how rigidity drops as Glycerin is added:



The 20% addition is a starting point. Different ceramic recipes may require more or less Glycerin.

Mixing directions

Add glycerin to Elmer’s. Mix thoroughly at low speed.

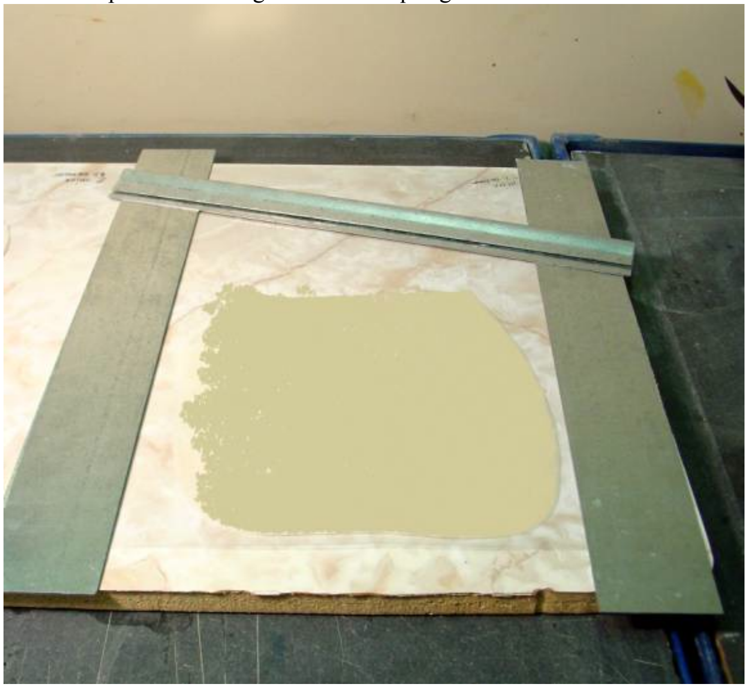
Slowly sift in the dry batch. Mix thoroughly at low speed to avoid foaming (Elmer’s foams when mixed too rapidly). This step should last a few minutes to ensure homogeneity.

If foaming has occurred, a few drops of a de-foaming agent may be used (we will use Cognis dehydran 1293 for this).

The slip should now be passed through a 60’s screen to ensure no lumps are left behind, and to pop any air pockets that may have developed during mixing (don’t forget to clean the sieve before the glue dries!). The slip should be used immediately after sieving and without further mixing so as to avoid reintroduction of air. This means that our casting area must be set-up before we start mixing.

Casting area

Casting occurs on a sheet of Mylar. A flat movable surface (plate glass is ideal) is sprayed with a spray adhesive. The Mylar is carefully applied over this so as to avoid wrinkles. Then the top of the Mylar is lightly coated with silicone spray. Sheet metal cut into strips is used as a guide for the squeegee to ride across.



Begin by pouring slip from left to right in sufficient quantities to last the entire surface (adding additional slip midway through a pull is not advisable). Drag material across in one continuous smooth motion towards you. You may want to tape the ends of the guides down so they don't move. When holding the metal squeegee try holding it perpendicular to the table so it doesn't flex (if it does flex, the cast will be thinner in the middle than at the sides, leading to potential problems). Allow the tape to dry (usually 24 hrs.) before removing the Mylar from the casting surface.

An example of tape casting a low fired mat glaze

I started with the following:

ATG #190 var1 (cone 04)

Neph Sy	8.32
Spodmene	39.82
Wollastonite	23.92
Flint	16.43
3124	11.52
Total	100.00

I used 35% water + 14.12 g (13.58 cc) of Elmer's + 3.53 g (2.89 cc) of glycerin for 100 g dry batch (15% addition of plasticizer and binder) (total water = 42.8 %). No dispersant was used. This is not enough binder for this recipe. The coating breaks up into a powder when it is removed from the Mylar.

On the positive side…

1) Prior to screening, Elmer's aerates during mixing, making the mixture very foamy. I had success removing most bubbles by screening it through a 60's mesh.

2) 42.8 % total water is enough to work this recipe. Interestingly, the Elmer's helps the powders flow better than water alone (an important consideration in a clay-less recipe like this). In this respect it handles like CMC gum.

In the next test, I will have to increase the total amount of Binder/Plasticizer to ceramic powder:

Try 30%, 45% and 60% binder/plasticizer

30% Elmer's/Glycerin to 70% dry batch: This translates into 30 x .80 = 24 g of Elmer's and 30 x .20 = 6g of glycerin for 70 g of dry batch. In a 100 g dry batch, this translates to 34.29 g of Elmer's and 8.57 g of glycerin. Since Elmer's contains 57.5 % water, we must subtract this from our target 42.8% water. So adding 34.29 g of Elmer's brings in (34.29 x .575 =) 19.72 g of water. We must subtract this from our required water in order to reach our target of 42.8%. So we will add (42.8-19.72 =) 23.08 g of water.

45% Elmer's/Glycerin to 55% dry batch: This translates into 45 x .80 = 36 g of Elmer's and 45 x .20 = 9g of glycerin for 55 g of dry batch. In a 100 g dry batch, this translates to 65.45 g of Elmer's and 16.36 g of glycerin. Since Elmer's contains 57.5 % water, we must subtract this from our target 42.8% water. So adding 65.45 g of Elmer's brings in (65.45 x .575 =) 37.63 g of water. We must subtract this from our required water in order to reach our target of 42.8%. So we will add (42.8-37.63 =) 5.17 g of water.

62.95% Elmers/Glycerin to 37.05% dry batch: This translates into 62.95 x .80 = 50.36g of Elmer's and 62.95 x .20 = 12.59 g of glycerin for 37.05g of dry batch. In a 100 g dry batch, this translates to 135.92 g of Elmer's and 33.98 g of glycerin. Since Elmer's contains 57.5 % water, we must subtract this from our target 42.8% water. So adding 135.92 g of Elmer's brings in (135.92 x .575 =) 78 g of water. This will put us over our target of 42.8%. We will not add additional water.

Results

30% Elmer's/Glycerin is not strong enough. Coating cracks when Mylar is removed from casting surface. Cracks when bent.

45% Elmer's/Glycerin similar to 30%, though noticeably more cohesive.

62.96% Elmer's/Glycerin. This is a classic 1.5 Binder/Plasticizer to 1 part ceramic mixture. This works! It can be bent without cracking. Separation from Mylar is finicky but can be done carefully. Still lots of bubbles in this but very fine bubbles (using dehydran solves this issue). Feels like lightweight soft foam when cured.

So….

Elmer’s 80%
→ Non-ceramics 62.96%
Glycerin 20%

Neph. Sy. 8.32 %
Spodmene 39.82 %
Wollastonite 23.92 % → Ceramics 37.04%
Flint 16.43 %
3124 11.52 %

While the ratio of Elmer’s to glycerin will probably work in most cases, the total amount of these in relation to the ceramic will vary based on the total surface area of the various ceramic ingredients. For example, Jesse Small has been tape casting silicon carbide and frit. He uses considerably less than the 62% non-ceramics I have reported above. Testing your specific recipe will be crucial...

Useful Calculations

How much water is there in Elmer’s Glue?

Wet weight 40.26 g
Dry weight 23.13 g
Total water in Elmer’s is 57.5%

Liquids converted to weight

Darvan 7
50 drops = 5.33 g
1 drop = .1066 g

Elmer’s
25 cc = 25.91 g
1 cc = 1.04 g

Glycerin
25 cc = 30.52 g
1 cc = 1.22 g

Dehydran
10 drops = .2 g
1 drop = .02 g