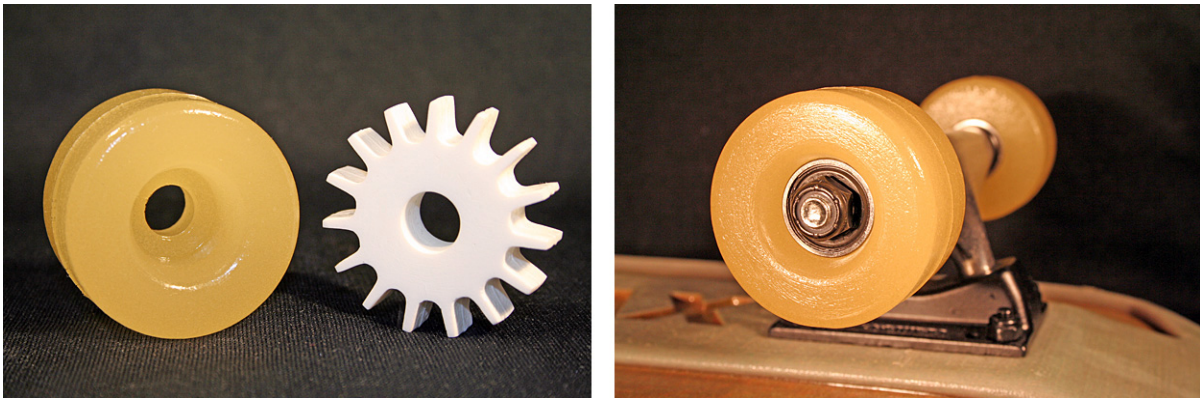


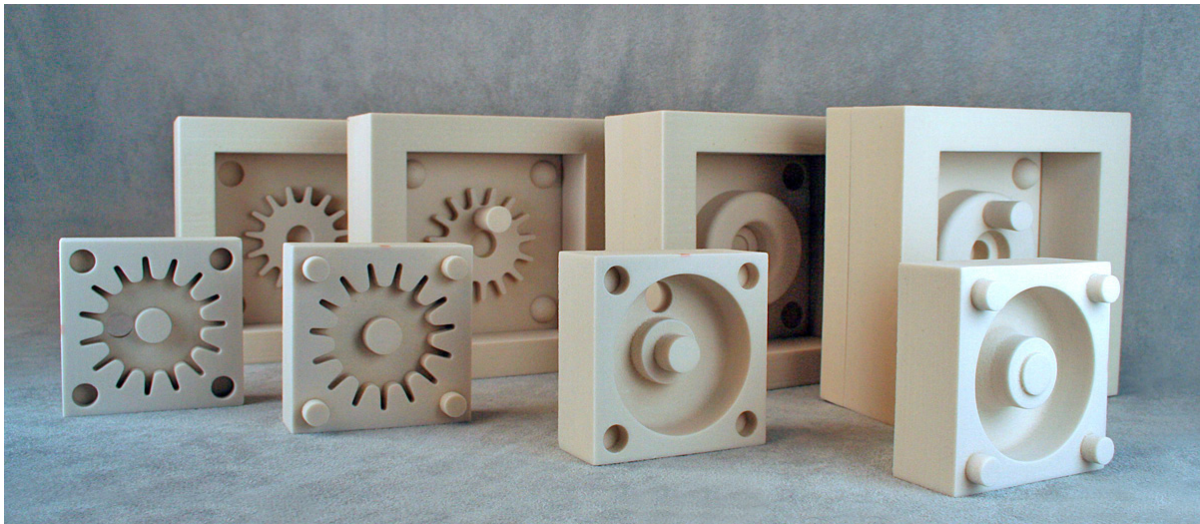
Functional Concept Modeling: Print Molds and Create Functional Urethane & Plastic Parts!

Dan Topjian - Application Engineer

We are often asked in the Application Engineering Group if a Z Corporation 3D Rapid Prototyping Printer can be used to produce functional urethane and plastic parts. The answer is undeniably yes! How, one might ask...? Well, although you cannot directly print urethane or plastic parts on a Z Corp 3D printer, you can, however, print plaster-based molds rather quickly and easily to accomplish this very unique and often over-looked application. In addition to printing plaster-based molds, plaster-based patterns (with mold boxes) can also be printed on a Z Corp printer to produce silicone rubber/urethane rubber molds. The option is yours.



Functional Urethane Skateboard Wheel & Plastic Gear! See wheels in action on page 9!



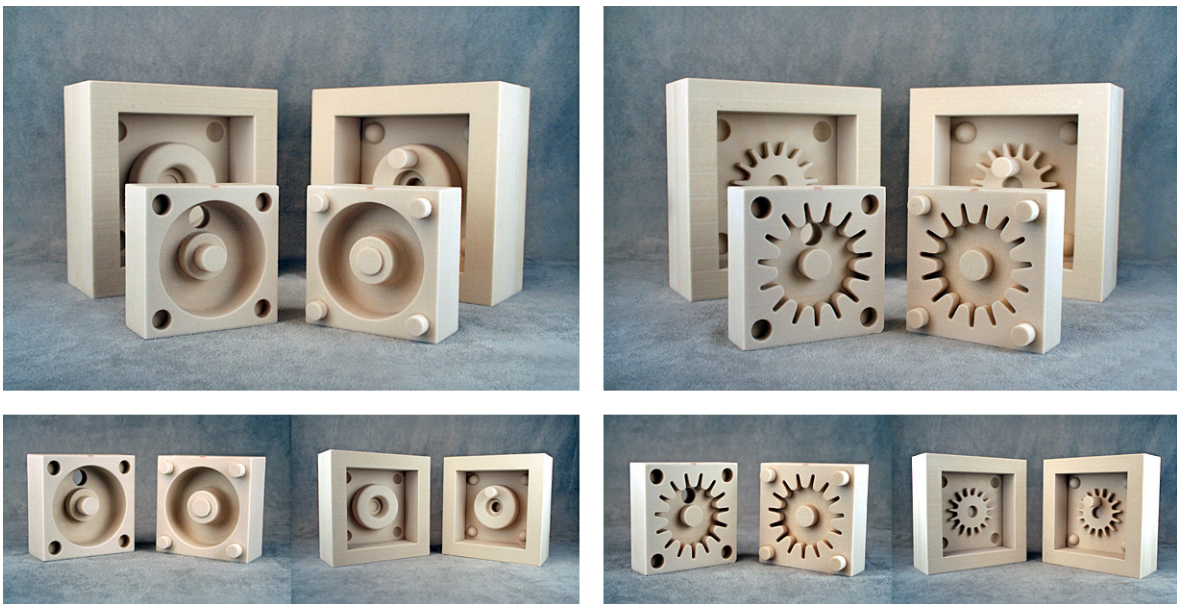
zp130 Plaster-Based Gear & Skateboard Wheel Molds (foreground)
zp130 Plaster-Based Gear & Skateboard Wheel Mold Patterns (with Mold Boxes) (background)

In this application note, the art of mold making will not be presented. Like CAD design and 3D modeling, mold making (especially designing molds) is a skill which must be learned and practiced.

Since there are many on-line resources to help assist you with your mold making efforts, we have provided some suggested websites to visit at the end of this application note. These websites will help better familiarize you with the overall mold making process. All molds within this application note were designed using Newtek's Lightwave 9 Modeler Software, and printed on a Z Corp Spectrum Z510 3D Printer. In addition, if you are looking for handy mold making design software, Materialise now offers forward engineering software called 3-matic with a tooling module for mold design, which you may want to consider should you decide to pursue the exciting world of mold making.

This application note, instead, will focus on what we feel is just the tip of the iceberg when it comes to the true potential of the various types of plaster-based molds and patterns that can be printed on a Z Corp 3D printer.

Since many folks all around the world have been making molds for many, many years (using a variety of materials), today's molds are predominantly made from flexible rubber products. Although flexible rubber can be used as a mold, and although it does offer advantages in certain situations, plaster-based molds can indeed also be used! In addition to showing plaster-based mold solutions, we will also show how you can use a Z Corp 3D printer to produce plaster-based patterns (with mold boxes) for producing flexible rubber molds. Shown below are both plaster-based molds and plaster-based mold patterns (with mold boxes) for producing both a functional urethane skateboard wheel and a functional plastic gear. All molds were produced using zp130 and Z-Bond 101 on a Spectrum Z510.



If you happen to be wondering when you should use a plaster-based mold or a rubber mold, let's take a look at our skateboard wheel mold above as an example. Due to its very nature, a urethane skateboard wheel is smooth and can easily be extracted / demolded from the plaster mold, thus allowing the mold to be used repeatedly. However, let's say we wanted to produce a ~1/8" deep tire tread pattern on the skateboard wheel. Since we would need to incorporate a ~1/8" deep tire tread pattern into the mold to produce the desired end result, extraction of the cured skateboard wheel may be very difficult due to the binding/locking nature of the treads within the circumference of the mold. We can certainly redesign our plaster mold (perhaps in sections) to allow for this desired tread feature, but in this case, using a rubber mold to produce the fine features of the tread may be more desirable. The rubber mold will allow us to bend the mold off of the finished wheel and reuse it for additional wheels.

Materials – Sealants, Compounds & Release Agents

For this application note we relied on the good folks at Smooth-On to supply us with the required Silicone Rubber, Urethane Rubber and Liquid Plastic materials needed, as well as Sealant and Mold Release Agents. All were reasonably priced and came with detailed mixing instructions. In addition, I would highly recommend visiting Smooth-On's website for more information on their vast product offering and also contacting their technical support line with any questions that you may have. They are very knowledgeable and can be of great assistance.

*** IMPORTANT WARNING ***

Safety First!

Please first read all MSDS (Material Safety Data Sheets) carefully!

Please first read all Product Overview Sheets carefully!

A well ventilated area with the use of a Fume Hood is highly recommended!

The materials we chose to use are listed below. These particular materials are easy to use compounds that allow for convenient one-to-one & two-to-one (by volume) mix ratios (no scale necessary!). In addition, vacuum degassing is not necessary for these listed materials.



Super Seal	Can Trial Size (1 pint) Used to seal plaster molds and plaster patterns.	
Ease Release 200	Spray Can (14 fl. oz.) A mold release agent for removing cured parts from OOMOO 30 silicone rubber molds.	
Univ. Mold Release	Spray Can (14 fl. oz.) A mold release agent for removing cured parts from plaster molds and plaster patterns.	
PMC-790	Trial Size (1 quart part A + 1 pint part B) Liquid Urethane Rubber Compound Used to produce skateboard wheel.	Mix Ratio: 2A : 1B By weight or volume.

OOMOO 30

Trial Size (1 pint A + 1 pint B)
Silicone Rubber Compound
Used to produce silicone rubber molds.

Mix Ratio: 1A : 1B
By volume.

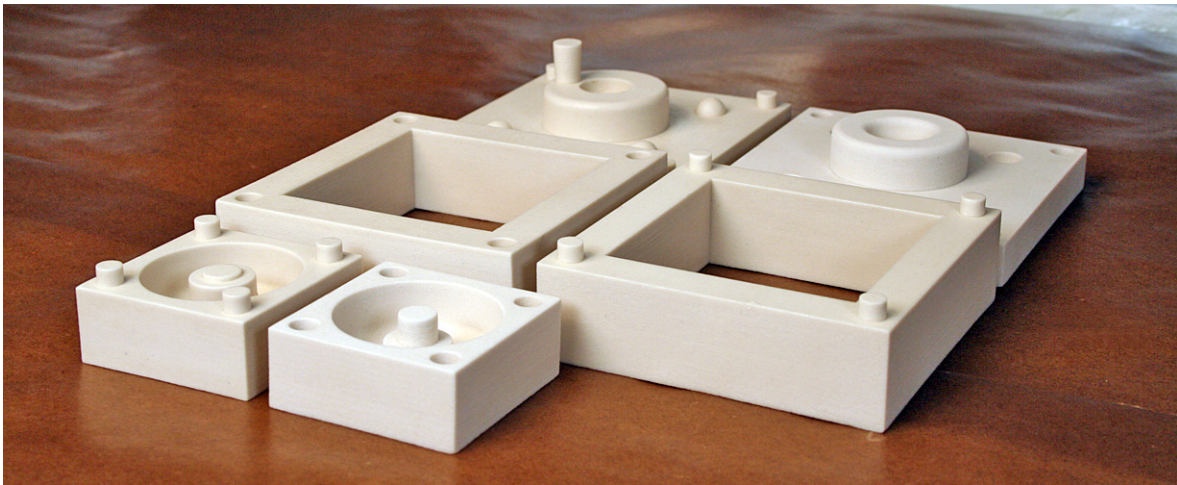
Smooth Cast 300

Trial Size (1 pint A + 1 pint B)
Liquid Plastic Compound
Used to produce plastic gear.

Mix Ratio: 1A : 1B
By volume.

Mold Preparation

After designing and printing your molds, you will need to sand the areas of the molds which will come in contact with the urethane or plastic. Pay particular attention to producing a smooth, finished surface. Any coarse areas will not only show up in the final cured urethane or plastic parts, but may also cause the compounds to bind to the molds, making it possibly difficult to remove the finished parts from the mold after fully curing. Using very fine grit sand paper, we carefully sanded both the skateboard wheel and gear molds to a smooth finish.



Please note the two mold box pieces above (top photo, center pieces); pieces which were also sanded. By designing our pattern mold boxes as shown above, it allowed us to use these parts as both mold boxes (for pouring the liquid rubber onto the wheel patterns), and as supports for the cured rubber molds, for pouring the urethane wheel.

Although it is not illustrated, we performed the same fine sanding procedure on the gear molds. To avoid redundancy, from this point onward, we will focus predominantly on the skateboard wheel mold. The same procedure and principal applies equally to the gear molds.

Sealing Your Molds



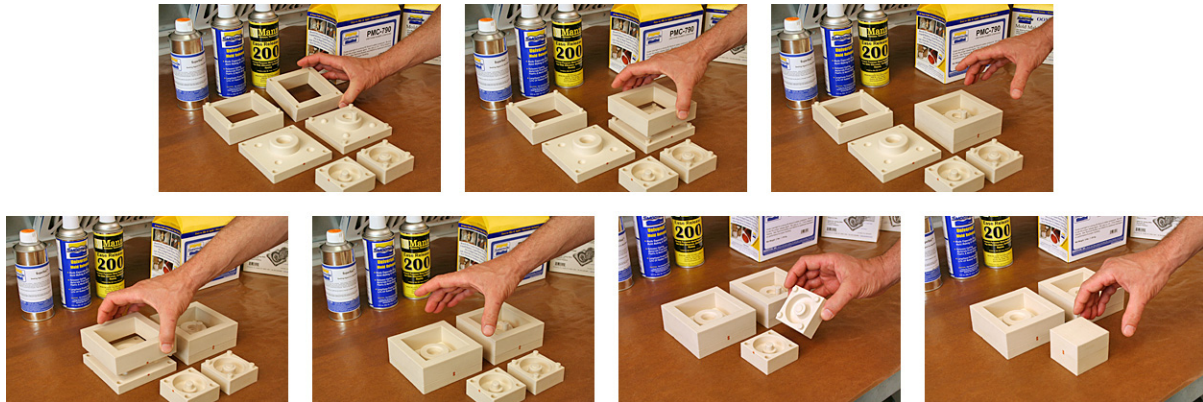
Since all plaster-based molds must be sealed, we used Smooth-On's Super Seal to seal the molds to avoid the compounds from potentially penetrating the Z-Bond infiltrated material. Although 2 (two) coats are required to seal most surfaces, we decided to use 3 (three) coats due to the porous nature of zp130. Ten minutes is the required drying time between coats, with a one hour dry time for the final coat. Using a brush, each coat went on smoothly, drying to an almost clear coat. We also chose to seal the entire mold for consistency.

Applying Mold Release Agent



For our skateboard wheel mold (top left & top center) we used PMC-790 liquid urethane rubber compound to produce the skateboard wheel. For our skateboard wheel patterns (and mold boxes) we used OOMOO 30 silicone rubber compound to produce silicone rubber molds. To help release both the cured wheel and rubber molds from the plaster-based molds and patterns, we used Universal Mold Release. Two light coatings (with ~5 minutes between each coating) were sprayed, and then brushed onto the compound areas. After which, we let the molds sit for another 5 minutes before pouring the compounds.

Assembling Molds, Mixing & Pouring Urethane & Plastic Compounds



Illustrated above is assembly of both our skateboard wheel mold patterns and molds. The three top photos show how you can get creative with your mold design and actually print plaster-based mold boxes to use with your mold patterns. If you're familiar with mold making, many folks in the industry construct mold boxes out of wood. However, with your Z Corp printer, you can let your printer do all the work. By using the mold boxes the way we have above, it will allow us to take advantage of this design when it comes time to joining our final rubber molds together. More on that a little bit later. The bottom four photos above show the simple assembly of the wheel mold. Please note the color key for joining molds together correctly. Since our design is a wheel, there's no real need for the key, but it is good practice. Also note that when you design your holes and pins to join the molds together, use standard drill sizes for the holes. This will allow you to bore the holes later, if required. Reducing the diameter of your pins by ~ 0.02 " should allow for a snug fit. When printing your molds, please remember to use Bleed Compensation to assure dimensional accuracy.



Using masking tape (or duct tape), tape around the seams of your molds to prevent leakage. Using PMC-790 Liquid Urethane Rubber Compound, we poured 2 parts A (yellow), and 1 part B (blue) into separate measuring cups (Mix Ratio: 2A : 1B by weight or volume). Please follow the directions. Since this compound required shaking and stirring of part B, we followed the directions before combining parts A & B together. After joining parts A & B, we stirred for ~ 3 minutes before pouring the mold. Please note, when pouring, try to make sure the stream filling the mold is thin and consistent. This will allow for the escape and reduction of air bubbles. Also, take a few breaks from pouring and both gyro and tap your mold so that the compound spreads evenly throughout, and releases air bubbles. PMC-790 (\sim Shore A Hardness: 90), \sim Cure Time/Demold: Overnight/16 hrs.



Repeating the last procedure, we taped the seams of both our mold boxes and we used OOMOO 30 Silicone Rubber Compound. This process produced our rubber molds (an option to our already created plaster-based molds). Using a Mix Ratio of 1A : 1B by volume, we poured and filled both molds. Although OOMOO 30 is not Smooth-On's strongest silicone mold rubber, we chose to use it due to its ease of use. In its mixed state, it has a very low viscosity for pouring. It requires no vacuum degassing and it cures at room temperature with negligible shrinkage. OOMOO 30 (Shore A Hardness: 30), ~Cure Time/Demold: 6 hrs.



Repeating the process yet again, we taped the seams of our gear mold (which like the skateboard wheel mold, was both sealed and coated with Universal Mold Release).

Please note that we also created rubber molds for the gear (using OOMOO 30), just like the skateboard wheel above. A photo can be seen at the top of the next page, bottom left photo.

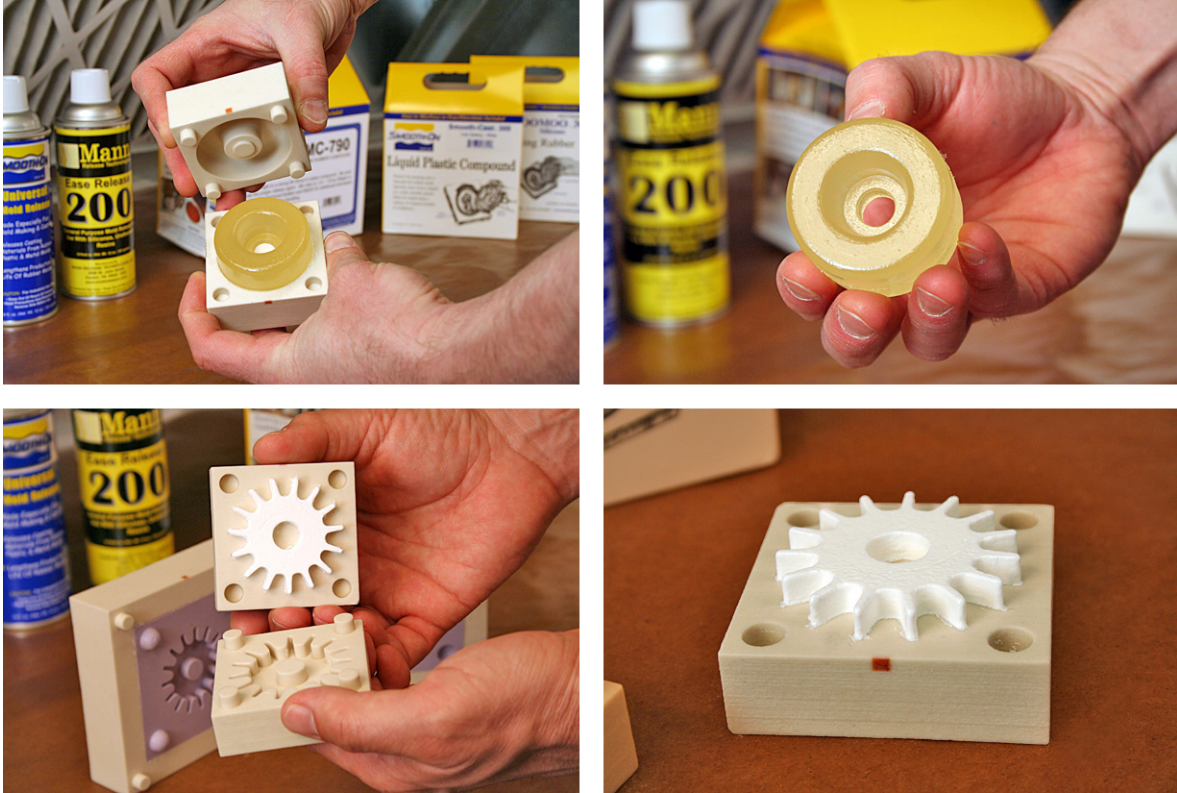
Using Smooth Cast 300 Liquid Plastic Compound, with a Mix Ratio of 1A : 1B by volume, we poured the mold. Like with the skateboard wheel mold, we made certain that the stream filling the mold was thin and consistent. This allowed for the escape and reduction of air bubbles.

Smooth Cast 300 is an ultra-low viscosity casting resin which is virtually bubble free. Like with our other casting materials, vacuum degassing is not necessary. In addition, this resin accepts and can be pigmented different colors. Fully cured castings are tough, durable, machine able and paint able.

Smooth Cast 300 (Shore D Hardness: 70), ~Cure Time/Demold: 10 min.

Finished Parts

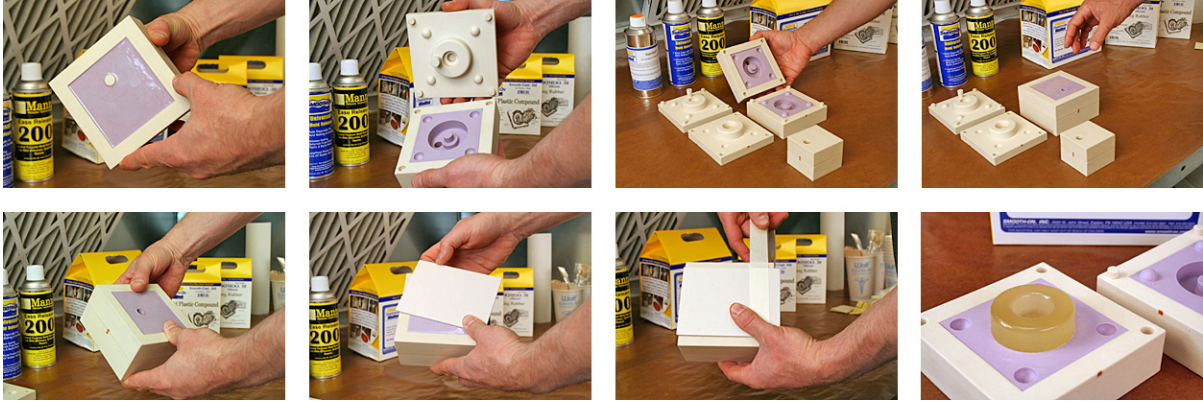
After allowing for proper curing time, Viola! Functional urethane and plastic parts!



As mentioned earlier, there will be times when a rubber mold may be better suited for a particular part that you are casting. Shown below is how we designed our mold boxes to separate, and then mate back together to join the rubber mold sections. There are stronger rubber compounds that can be used to avoid the use of the mold boxes. In this case, however, it helped serve two purposes; both for pouring the liquid rubber to form the mold, and as support structures for the rubber molds for pouring both the urethane and liquid plastic.

When using OOMOO 30, it is recommended to use Ease Release 200 (mold release agent) for demolding cured parts from OOMOO 30 silicone rubber molds.

Also, please read all instructions. When using OOMOO 30 to make molds, it is recommended to post cure the rubber mold an additional 4 to 5 hours at 125°F (51°C) in a convection oven. This will help eliminate any residual moisture and alcohol (a by product of the condensation reaction). Allow the rubber mold to cool to room temperature before using. Do not cure rubber where temperature is less than 65°F /18°C.



Wheels in Action!



Wheels on Z-Max skateboard (top). Swapped wheels to a wider, longer board.

To view the Plaster-Based Molds Video, please visit Z Corp's 3DP User Website www.3DPUser.com

***** IMPORTANT WARNING *****

The Z-Max skateboard is not intended for actual use by children, young adults or adults. It is not to be used as a substitute for a fully manufactured, tested, commercial skateboard. Its intent is solely for rapid prototype functionality and display purposes only.

Conclusion

As originally mentioned, we have touched on just the tip of the iceberg regarding molds and castings. Make no mistake about it, you can use your Z Corp 3D printer to produce plaster-based molds to create functional urethane & plastic parts. Like any new process, you will likely make some mistakes at the beginning. The trick, however, is to learn from your mistakes and produce great parts!

For those who recall my application note about printing a skateboard deck on a Z Corp printer, and infiltrating it with Z-Max for superior strength, we have yet again used a Z Corp printer to produce functional parts; four functional skateboard wheels and a functional plastic gear. All that remains, is casting the skateboard trucks/axels – perhaps with Z Corp's ZCast 501 for the molds!? Perhaps...

Additional Resources for the Novice Mold Maker

www.smooth-on.com/moldmaking.htm

www.build-stuff.com/002book.htm

www.eagerplastics.com/intro.htm

www.theminiaturespage.com/ref/fgmolds.html