Concrete 3D Printer User Guide

P21652

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Getting Started

About this Printer

The creation of this printer was to aid RIT student teams or groups that required medium sized prototyping. The ability to have a concrete printer provided users with a cheap, effective, and fast way to model medium sized objects. Two examples of this printer's capabilities are the MSD project Arborloo and the Concrete Roof Tile projects. First, the Arborloo team spent years developing an Arborloo out of a 5 gallon bucket and cement disks to create a sustainable toilet. They attempted to hand shape the two foot disk at first. This was lumpy and too uncomfortable to expect users to sit on the toilet. The next method attempted was a mold. Unfortunately, due to the large size of the mold, there were several demolding breakages. Second, the Tile team struggled with needing several molding steps to create the expected S-Shaped roof tile. This process took weeks to prepare enough of the correct items for their final demonstration.

The concrete printer is designed similar to commercially available plastic 3D printers. The frame is made out of slotted aluminum steel. This provides a sturdy structure. Mounted to the frame is our guide rails for the X, Y, & Z axis. Each of these consists of a ball screw system partnered with their own respective stepper motors. When a command is sent to the stepper motor it provides a consistent movement and thus creates each of our axis motions. The motors are controlled from a WIFI Control Duet Board. This additionally, powers the auger and processes the G-code provided by the user. The auger is part of the extruder system which provides the flow of concrete to create the official print.

Is this Printer Right for you?

This printer is right for you and your team if you meet the following criteria:

- Already have a relatively simple print
- Understand GCode or willing to learn + manually generate GCode
- Have multiple people available to use the printer, as it really requires 3+ people to effectively operate. 1-2 people can do it if they are experienced with the printer, and one person is going to have a very difficult time and we would strongly recommend at least 3 people.

If your print involves:

- Fine detail
- Complex geometry that cannot be broken down into lines/arcs
- Overhangs

Then this printer may not be able to produce the results you desire. Overhangs could be solved by printing an initial piece (for example, a dome shape), letting it set, then printing again over it with a garbage back or something over the dome structure. Once the 2nd print sets, you'll have the dome shape underneath providing the necessary structure for the overhang of the 2nd print.

Set Up

GCode Generation

Currently the Cura profile does not generate the correct GCode with speed control. The matter of slicing software is for a future iteration of the team/project. That being said, GCode must be manually generated. This link is helpful for understanding GCode. It is a slightly painstaking process to create GCode by hand, but it's the only way right now.

The G-commands are what to use for this. Whatever object you are trying to print, break that model down into simple movements like straight lines and arcs. Then, create the GCode script based on the lengths of said movements. The GCode works in **millimeters**, so make sure everything is sized appropriately.

Another important thing to include when creating the GCode, is that if you want speed control you must adjust the PWM sent to the "E0 Heater" pin. Details on this are provided in the Electrical Documentation.

Assemble Printer

The printer should not be in a state of complete disassembly. If it is, here are the assembly instructions.

Typically everything should be set up already. The extruder should be mounted onto the X-axis—if it is not, 4 screws and 5 minutes will have it mounted. The Duet and motors are all wired up already. Simply plug the extension cord into an outlet, flip the switches, and you should have power. If the printer needs to be moved, the leveling casters can lock/unlock and the printer can be moved. The bed can also slide in/out and can be adjusted such that it is level with the printer.

Homing

The X-Y axes home using limit switches, so homing those axes are as simple as turning the Duet on and hitting the "Home X" and "Home Y" buttons. The Z-axis homing uses a Z-probe, so the homing functions a little differently. If the Z-probe is not wired, follow the instructions under "Z-probe" in the Electrical Documentation. Once wired, attach the nozzle with the Z-probe to the extruder head. Then, home Z. It should move all the way down and stop 1 millimeter away from the bed. Then, take the nozzle off and you can put it away as the homing for the whole printer is complete.

The reason for this is simply we do not want the Z-probe to be around concrete since it would take very little to destroy the probe. Thus, we made the homing separate from the printing.

Concrete Recipe

At this time we recommend that you use one of the following:

- Veneer?
- Sakrete Type S Mortar Mix
- Sakrete Type N Mortar Mix

DO NOT USE ANY MIX WITH AGGREGATE OR ANY MIX WITH STONES. This will break the printer!

Here are the mixing steps we found most helpful.

For a small batch:

1. Gather a small mixing bucket, kitchen scale, scooper, mixing stick, and water.
2. Zero scale with bucket on top.
3. Scoop in desired amount of concrete. Example: 4000g
4. Calculate your water amount using the formula below
    a. Water (g) = Concrete (g) x 18%
    b. Water (g) = 4000g x 18% = 720g
5. Add calculated amounts of water directly to the bucket of concrete.
6. Mix by hand until all clumps are gone. Besure to get bottom corners.
7. Use concrete within 45 minutes of adding water.

For a large batch:

1. Gather a small mixing bucket, large scale, scooper, drill with auger attachment, and water.
2. Zero scale with bucket on top.
3. Scoop or pour in the desired amount of concrete. Example: 30lbs
4. Calculate your water amount using the formula below
    a. Water (lbs) = Concrete (lbs) x 18%
    b. Water (lbs) = 30 lbs x 18% = 5.4lbs
5. Add calculated amounts of water directly to the bucket of concrete.
6. Mix using the drill with auger attachment until all clumps are gone. Besure to get bottom corners. **Warning**: Auger is sharp so be careful.
7. Use concrete within 45 minutes of adding water.

Running Your Print

Loading Print File

With your GCode, simply copy and paste it into a macro in the Duet Web Controller. More detail on the DWC and its sections can be found in the Electrical Documentation, but basically:

- Go into the **Macros** section of the DWC

- Create a new macro with a button on the right
- Paste in the GCode
- Save and exit
- Run macro

Feeding Concrete in

Concrete must be hand-fed into the extruder in the current version of the project. The hopper and tube put too much weight on the motion axes for it to move, so a revision of the X-Y motion is needed for greater stability and movement capability. That being said, hand feeding is the current method. Once the concrete is mixed, spoon it into the extruder using a trowel. The extruder should be filled with concrete before the macro is run, so the steps are as follows:

- Mix concrete
- Feed concrete in
- Run extruder through DWC for about 10 seconds, keep feeding concrete in so the system is full of concrete
- Run macro
- Feed concrete in at a steady pace
- Observe the quality/width of the print and adjust feed-rate as needed

If concrete is fed in too quickly, the bead width will be pretty large. The converse is also true, if not fast enough, it will thin out in spots and the resulting print won't be as intended. However, if your intention is to create a large/small bead width, **you are able to feed faster/slower in order to accomplish this**. For example, if you desire the first/bottom layer of the print to be the widest, you can feed the extruder quickly and apply pressure to the concrete in order to create a larger bead width.

If the print did not turn out as desired, you can simply reuse the concrete. Just slide it off the bed back into a bucket/container, and reuse. **However,** the concrete must still be workable. From our observations, it takes about 45 minutes to 1 hour for concrete to no longer be workable in the system. Try and have everything ready before mixing concrete, and once the concrete is mixed, move quickly. If you use concrete that is no longer workable with this printer, not only will the print not turn out well, but it will make it difficult to clean the extruder out after printing. The longer concrete is left in the extruder, the harder it is to clean it out.

When the Hopper is ready to be used the expected safe usage and the method of use that was done during the testing of the hopper goes as follows:

FOR ENTIRE TEST ENSURE NO STUDENT HAS ANY BODY PART UNDERNEATH THE HOPPER

1. Connect the wide end of the corrugated tubing to the outlet of the hopper and then using metal cable clamps secure the tube to the outlet.

2. Connect the braided handle of the hopper harness and hang it to the winch hook.
3. Lowered to the minimum fill height and the printer was moved to accommodate easy access to the hopper. The tube was not connected to the extruder and the outlet of the hopper was blocked with a sheet of plastic that could easily be pulled out as well as the outlet of the tube was kept elevated above the rim of the hopper.
4. Fill the hopper with mortar and then the hopper is then lifted just high enough to clear the upper edge of the printer. Once this was done the printer was moved such that the hopper hung near the middle of the x-y print envelope. The hopper should once again be lowered to the point of the tube touching the print bed. At this point it is safe to connect the outlet of the tube to the extruder using hose clamps.
5. Once the tube is connected to the extruder remove the plastic sheet from inside the hopper to allow for mortar to flow through the hopper into the tube.
6. Lift hopper to max operational high such that the bottom of the hopper is sufficiently high enough to keep tube from bending at a 90 degree angle and all points of extruder motion.
7. Having the hopper above the printer provides a physical barrier keeping users from standing directly below the elevated hopper. However it is noted that it impedes easy access to fill the hopper during a print.

Reloading Concrete Mid-Print

As the current method of printing requires hand feeding instead of a hopper, there is no reloading necessary. Once the hopper is functional, this section should be revisited.

Remove Print Bed

The print bed has been made to be removable. At this time only one print bed exists but if another is wished to be created the CAD drawing is available in the ConcRIT 2.0 drive. The reason for a second includes having a print that is too large and/or unstable to to take off the print bed but a need to get the next print started.

To remove the bed, first raise the z axis high enough as to not bump the new print. Check to make sure the print is stable enough to be rolled put and on the surfaces it will cross on its move. The print bed comes with a metal handle bar that also works as a foot pull. Please pull the item out first with your foot using the handle then the remainder can be completed. **Safety**: Please use proper lifting technique to not injure yourself.

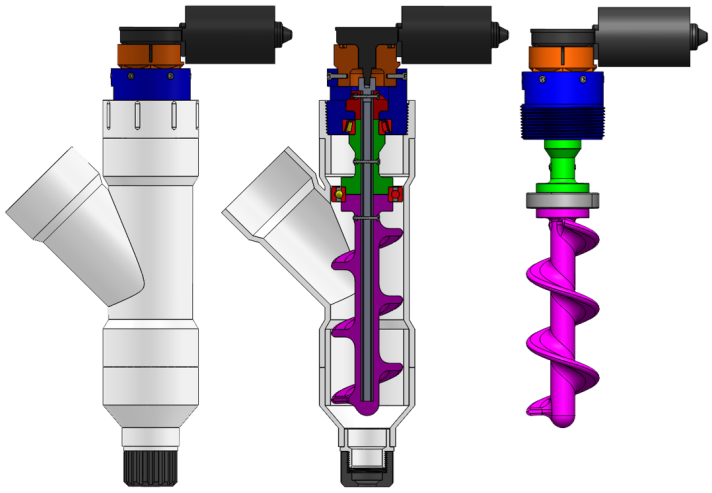
Once the print has dried it is good to be removed from the print bed. Please be mindful that if you have a thick print, it may not be dry enough on the inside. It is recommended that a plastic sheet or plexiglass panel is laid. It is recommended that you give more than 24 hours for any item more than 4000g of concrete when moving the print off the drying rack. These can be

moved from the bed but it is needed for the drying time. Once a print is dry you may use a scraper tool to aid in separating the print from the panel.

Tear Down

Clean Up per Sub System

Electrical: No cleanup necessary. Make sure all power supplies and the Duet switch are turned off, then unplug the extruder DC motor leads so the auger can be removed.



Extruder: This is by far the most important part of cleanup. If concrete sets inside this component, the entire extruder will be unusable and must be remade. Including a picture above for reference to parts—the colors referenced are in relation to the picture above, not the colors of the physical components. The printed components can be any color.

- Once the leads to the DC motor are disconnected, unscrew the blue component from the PVC pipe. It might be a little difficult to get out, we found that holding the PVC in between your knees and twisting works. If 2 people are available, have one person hold the PVC and one person twist the motor/3D printed part. It's difficult to hold so effort is needed.
- Once the component is unscrewed, the entire auger/motor system will come out of the PVC pipe. Now the extruder is separated into two pieces. Please be aware that the bearing/auger might try and slide off the shaft. This is okay, just put them back together at the end and try and keep concrete away from the bearings.
- Clean the auger well. Clean the PVC pipe well, we found that a toilet brush works well for cleaning the PVC.
- **Please clean the threads of the extruder.** When pulling the auger out of the pipe, sometimes concrete gets on the threads on the inside, top of the PVC. If it hardens, it will not be possible to screw in the motor/auger again. It is imperative that the threads are properly cleaned.

- Dry the components as best you can by hand. Then leave components disassembled on a towel to dry. Once dried, it can be put back together and re-mounted to the printer.
- Spray some WD40 into the bearings to prevent any corrosion.

Disassembly

At this time the printer can remain most together in “Disassembled State”. It was deemed impractical and time consuming to entirely take apart. Additionally, this poses risks to calibration requirements.

Disassemble state is defined as the following:

- All equipment must be thoroughly cleaned
- Print bed to be secured to frame
- The hopper is to be removed from the lift
- Hopper placed on print bed
- Extruder bolted back in place
- Electrical cords unplugged from extruder
- Computer wires and extension cord detached and coiled nicely on frame mount
- Duet control board tucked away with cords laid nicely