

Specifications of Laboratory scale 3D concrete printer

1. Printer requirements:

- **Printer type:** *Gantry based 3D printer*

[Note: The printer must be robust and must provide continuous, seamless and stabilized printing solutions i.e., the movement and vibrations of the subcomponents must not affect the printing process and the printed object in any manner]

- The printer should have automated printing system.
- **Build volume:** *1000 mm X 1000 mm X 500 mm* (minimum)
- **Number of axis:** *4 axes* (X, Y,Z axes and rotation of the nozzle about the Z axis or the vertical axis)
- **Print speed:** *10 – 100 mm/s*
- **Position and/or Path repeatability:** *0.2 mm*
- **Machine travel speed:** *120 mm/s* (max.)
- The printer should be fully equipped with a control system and software that automates the printing process.
- Extruders which can be interchanged and modular should be provided with the systems. Multiple extruders of circular and prismatic cross-sections should be pre-supplied with the printer. Nozzle sizes can vary between *10 mm to 40 mm* with minimum number of nozzles should be 4 nos.
- Minimum movement speeds shall be *100 mm/s (X), 100 mm/s (Y), 40 mm/s (Z) and 50 rpm (theta)*.
- Minimum layer height for extrusion of *10mm*.
- **Print precision:** The printer should be capable of precisely printing using fibrous reinforcement materials (made up of commonly used materials in cement concrete)

2. Accessories:

2.1 Nozzles:

- **Nozzle cross sectional shapes:**

The print head should be capable to support different and basic nozzle cross section shapes such as circular, rectangular (sharp or rounded corners), square (sharp or rounded corners) and oval.

- **Nozzle dimensions:**

- Circular nozzle must have diameters ranging from *10 mm* to *40 mm*.
- Non-circular nozzles such as square and rectangular must have width ranging from *10 mm* to *50 mm* and thickness ranging from *10 mm* to *20 mm*.

- **Nozzle customization:**

Provision for usage of customized nozzles with following probable changes, but not limited to –

- With sides and without sides [Sides provide the flushing effect by trimming excess projecting materials from the previous printed layer. Also, it ensures the filament

geometry is well controlled. These sides aid getting a superior finish of the object printed]

- Modifications to the cross-sectional shape of the nozzle with additional mountings or notches
- Modifications to the interior surface characteristics of the nozzle

2.2 Extruder and hopper:

- **Screw Extruder** with an integrated hopper of at least **10 – 15 kg** material storage capacity. There should be provision for continuous feed of the material to the integrated hopper even when the printing is in operation. Also, the speed of extrusion i.e., the rotation of the screw extruder must be user controlled (at the user-software interface) to create different extrusion pressure for different mixture composition used.
- Extrusion pipe of at least 1.5-inch diameter and nozzle

2.3 Extra provisions for future modifications to/usage of the 3D printer:

- Provision for enclosing the print space / volume by a glass (or any suitable material) enclosure for creating a constant and controlled ambient conditions for printing and the material printed.
- Note: The enclosure must be modular (i.e., mountable and demountable as when required)
- Provision of (pump-nozzle) assembly as an alternative to (hopper-screw extruder-nozzle) assembly. The (pump-nozzle) assembly and its working should be capable of being integrated with the existing software and other hardware components.

3. Materials to be printed:

The printer should be capable of printing any cementitious systems which includes the following or a combination thereof –

- Ordinary Portland Cement (OPC)
- Supplementary cementitious materials used in cement concrete
- Alternative cementitious materials
- Aggregates (used in cement concrete) having a maximum size of *8 mm*
- Commonly used chemicals in cement concrete
- Commonly used fibres (secondary reinforcing materials) in cement concrete.

4. User - 3D printer interface (Software):

Simple, robust and user-friendly interface –

- That allows the user to model and slice the desired object of any complexity
- That simulates and displays the entire 3D printing operation (before the actual printing) and its associated parameters such as time of printing, material consumption rate, print rate, optimum 3D printer position and all other relevant information.
- That communicates the operator the necessary safety information and errors in the entire process appropriately.
- That allows for a single point and integrated control of all the sub-components such as print head unit and others for a synchronized printing mechanism / action.
- That allows for start-pause-change-resume workflow.

5. Hardware requirements:

1. An arrangement should be made to easily remove printed samples with the print bed being replaceable by another print bed if necessary.
2. A flushing system integrated with the pump or separately has to be provided to remove concrete from the printer. System should have enough pressure generation capability.
3. A pumping system capable of printing with larger aggregates (minimum 8 mm) has to be provided separately.
4. A mortar pump that can print with low aggregate content mortar is necessary (aggregate size 1- 2 mm).
5. The pump, printer and any other integral system should be controllable from the same software and a demonstration of this system has to be shown
6. Automatic cleaning system for the hoses and the nozzles should be provided.
7. Minimum material quantity the pump can print in one printing cycle should be at least 80 kg.
8. Computer-based controls and computer shall be supplied. A branded computer with a latest processor, 2TB and 8GB RAM shall the supplied.
9. A progressive cavity-type pump capable of handling the pressure for pumping concrete.

6. Scope of supply & incidental services: As per above specification

Specifications of Full scale (On site) 3D concrete printer

1. Technical specifications overview:

- **Printer type:** *Gantry based 3D printer*

[Note: The printer must be robust and must provide continuous, seamless and stabilized printing solutions i.e., the movement and vibrations of the subcomponents must not affect the printing process and the printed object in any manner]

- The printer should have automated printing system.
- **Printing height:** 8 meters minimum (Z Axis)
- **Print area (minimum)** : 8 meters x 8 meters (X Axis x Y axis), Print area should be expandable as per requirement in X and Y axis (up to 15 meters)
- **Transportability:** Should be able to disassemble and move on standard trucks / mobility platforms
- **Qualification:** To be used in open space
- **Types of nozzles:** Circular, Rectangular, Square
- **Motion axes:** (X, Y, Z, rotation)
- **Print speed:** Upto 25 kg/min; Minimum 250 mm / sec
- **Material:** Concrete (with maximum aggregate size of 8 mm), Clay, Ceramic paste
- **Material pumping and delivery system:** Capable of printing aggregate-based material precisely ; Capable of continuous material delivery
- **Maximum aggregate size:** 8mm
- **Nozzle control mechanism:** Automatic shut off of material
- **Mixer type:** Pan mixer or Continuous mixer with pump
- **Software:** Software designed for 3D printing concrete and material management

2. Detailed Technical Specifications

Motion System

- **Precision:** +/- 1 mm
- **Motor:** Servo/Hybrid stepper
- **Rotation(c) (minimum):** 60 rpm
- **Motion mechanism:** Slide on slide/ rack and pinion/ ball screw

Delivery system

- **Material delivery system type:** Positive displacement pump
- **Delivery pressure (minimum):** 30 bar
- **Viscosity range:** 40,000-200,000 cP
- **Flow rate:** Minimum 1000LPH
- **Hose Pipe:**2-3 inch diameter
- **Material:** Concrete, clay, ceramic paste
- **Maximum aggregate size:** 8mm
- **Shutoff mechanism:** Automatic
- **Finish:** Hard chrome coating or equivalent in material contact zone

Cleaning system

- **Hose connection:** Quick coupling
- **Hose cleaning:** Using 2 inch/3 inch medium soft concrete hose cleaning ball
- **Water flushing:** Water purge cleaning
- **Water jet:** Bosch or equivalent high pressure washer, 1500W, 125 bar (minimum)

Nozzle System

- **Nozzles:** Interchangeable (at least 4 to be provided)
- **Nozzle shapes:** Square, circular, rectangular
- **Nozzle shutter:** Automatic
- **Nozzle size:** 10-50 mm dia or upto 80 mm length in rectangular
- **Nozzle finish:** Hard chrome coating or equivalent
- **Delivery mechanism:** Hopper with control at nozzle
- **Additive Mixing:** System to mix additives or admixtures at the nozzle assembly

Software

- **Control Software:** Custom software designed for concrete 3D printing
- **Slicer:** Custom dedicated slicer for concrete 3D printing
- **Parameters:** Print Speed, Layer height, Nozzle selection, Flow rate multiplier
- **Printer and Printing Management:** Software controlled
- **Connection to machine:** USB/Ethernet
- **Supporting OS:** Windows 10 and higher
- **Input 3D model file format:** .stl
- **Functions:** Loading 3D model, Slicing 3D model, Monitoring the printing parameters, Manual Control
- **Manual Control:** X,Y,Z,C, Pump and extrusion
- **Layer Height:** Adjustable, 10-40mm based on the nozzle

Sensors

- **Limit switches/Proximity sensors:** X,Y,Z,C, Pump, Valves
- **Concrete Pressure:** Flush type pressure transmitter
- **Layer height:** Laser height sensor

Mixer

- **Type:** Pan mixer or Continuous Mixer Pump
- **Blades:** 4/5 nos
- **Capacity:** 200-250 kg
- **Number of mixers:** 2 nos if Pan mixer else 1 nos of Continuous mixer pump

Power Requirements

- **Power:** Adequate 3 phase power supply; Clear requirements to be provided

Computer Requirement

- **Computer:** Computer-based controls and computer shall be supplied. A branded computer with a latest processor, 2TB and 8GB RAM shall be supplied.

3. General requirements:

- Modular Gantry System where the size can be modified with maximum dimensions being constrained. The size should be modifiable for various construction site requirements
- Mechanism for base stabilization at construction site for ensuring better print quality
- System should be designed for easy assembly and disassembly for rapid erection and transportation to construction site
- System should be modular enough to be transported by standard trucks available
- System should be modular enough to be erected using standard cranes and facilities available at construction sites
- Planning methodology for printing more than 500 sq ft based of one floor in a continuous manner without disassembly and assembly
- System should be capable of printing a G+1 structure continuously
- Software and slicer designed and built for the application of concrete 3D printing. UI and advanced features makes it easier to 3D print with concrete with advanced material and process management
- Automatic nozzle shutoff valves to minimise manual intervention
- Continuous or Batch pumping system to transfer and pump high viscosity, high abrasion mixes to the nozzle
- Aggregates up to 8mm can be used which helps in reducing the cost of the mix.
- Printer should be designed to be used as an Off-Site module production printer if the need arises

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