Project Aim: To develop a 3D Concrete Printer (CNC Router Machine based) capable of moving in 3 Degrees of Freedom

(X,Y& Z). Machine length along 3 axes would be 1.5m x 1.5m x 1.2m with nozzle movement (1m x 1m x 0.5 m) capable of printing 3d Concrete structure elements. Printer will accept sliced 3d file inform of Gcode to interpret movement of nozzle with the help of stepper motors and Arduino circuit.

Scope of Work:

The Objectives of work will be to develop a 3D Concrete Printer and mix design suitable enough to print model(s)to justify all related properties. Design and manufacturing of extruder and nozzles of varying sizes and shapes. Addition of different polymers and additives to mix design to overcome different challenges associated with the concrete printing . Different equipment and software will be used to print and justify parameters associated with the printing of concrete so that analysis could be derived to use the printer on larger scale in construction industry.

Research Purpose:

Specific testing and experimentation facilities and resources are required at design phase of the printer its calibration failsafe testing and for printing, testing of rheological parameters of concrete in fresh state and printed hardened state.

Targeted Print Objectives:

1. 3D concrete printer with extrusion based digital fabrication.
2. Gcode for concrete printed structures.
3. Hit and trail testing to develop simplest possible mix design having suitable printability, extrudability & buildability.
4. Partial replacement of cement in the mix design with other cementing materials to have more advantages and feasibility for mass production.
5. Impact of changing shapes and sizes of nozzle on the printed layer properties.
6. Incorporation of troweling mechanism for more finished surface.
7. Incorporation of different materials in between the layers to predict its behavior in larger scale production.
8. 3D printed shapes of concrete predicting their possible uses in construction at large scale.
9. Uses of anisotropic behavior of 3d concrete printing in layers.
10. Target is to print structural element like fiber reinforced beam to get strength near to conventionally casted concrete.

- Making of freeform structural shapes and their validation through different software for usage at larger scale.
- To mitigate metal reinforcement challenge of 3d concrete printing.
- Validation at smaller scale for implementation at larger scale production.

Targeted Rheological Properties.

It involves continuous consideration and improvement of the mix design along with vma and other admixtures.

1. A fundamentally new way will be to actively control rheology and stiffening using real time sensors and accurate calibration of position of print head and integration of direct injection or spraying of setting admixtures immediately after extrusion from the print head.
2. It becomes even more important in view of well understanding the consequences of the different production conditions compared to traditional formwork-based casting operations. Which require non generic testing and simulation tools and equipment. Which include simulation test Subsequent Layer loading simulation, Function Controlled Compression testing ,Structural optimization & Functional hybridization
3. Optimization of the print speed of 3D concrete printers by the application of various methods and testing, in comparison, to already made 3D printers to decrease the buckling effect. Recording the energy consumption of motor to evaluate the extrudability of 3DCP.
4. Adjustment of the filament layer height to increase the efficiency of the printer without compromising the strength of the object.
5. Using various shapes of nozzles i.e., circular, ovular & rectangular to study the effect of strength, stacking of each layer, and surface finishes.
6. Various tests will be adopted to ensure the best quality of the material. Some proposed tests are the Carbonation Test for testing the chemical composition of concrete, Slump test, consistency test, and Rheological properties using a rheometer. Mini cone test and flow table test are performed to check the pumpability and extrudability of the mix.
7. To rectify the buckling in the subsequent layers of the mix which is common in 3DCP. Methods and testing will be employed to cater for this problem. The elastic is caused by loss of geometrical stability.
8. Plastic yielding is caused by maximum stress at the wall bottom reaching the material yield strength.
9. Testing the durability of the structure by various testing such as capillary water absorption, air permeability.
10. Modeling of 3D printed concrete structures using SIMULIA Abaqus which is a main finite element solver, Rhinoceros 3D, Sledworks. Splicing the generated STL File with any Splicer and using its G Code file for the arrangement in MATLAB and PYTHON.

Future Uses:

1. Highly effective in-terms of pre-cast structure manufacturing.

2. Mass production of customized complex structures.
3. Enhanced productivity at larger scale.
4. Cost and time effectiveness for larger scale projects.
5. Success of this project will eliminate the need of conventional formwork/molds on larger scale.
6. Reduction of manpower and post construction waste.
7. More architectural freedom/ ease in achieving free form architecture.
8. Cost effectiveness for complex shapes (i.e., non-linear shapes) at every scale.
9. More potential for research and usage.