**A Study on Challenges and Future Prospects of Contour Crafting Technology**

M.U Sreelakshmi1, Basima2, Riyas M R3

¹Civil Engineering Department, Royal College of Engineering and Technology, Thrissur, Kerala

² Civil Engineering Department, Royal College of Engineering and Technology, Thrissur, Kerala

3Civil Engineering Department, Royal College of Engineering and Technology, Thrissur, Kerala

1sreelakshmi.mu@gmail.com; 2 basimahassan02@gmail.com;

Abstract*—* ***This journal aims to explore the challenges faced by contour crafting technology, as well as its prospects. Contour crafting, also known as 3D-printed construction technology, has gained significant attention in recent years due to its potential to revolutionize the construction industry. The technology utilizes robotic arms to rapidly construct buildings by depositing layers of concrete or other construction materials. However, like any emerging technology, contour crafting faces several challenges that need to be addressed for its successful integration into mainstream construction practices. Additionally, this journal will discuss the prospects and potential applications of contour crafting technology in various industries.***

***Key words- “Contour Crafting”, “3D printing technology”, “ layered technology”, “ additive”, “viscosity”, extrudability”***

1. **Introduction**

Contour crafting is a newly emerged 3D printing technology that is simplifying the construction process at present and in future. Automation is construction industry was constantly evolving but construction of large structures at many times remained as a manual practice this can be due to lack of knowledge on technological updation. An automation approach like CC is layered fabrication, generally known as rapid prototyping (RP) or solid free-form fabrication (SFF). Although several methods of rapid prototyping have been developed in the last two decades, and successful applications of these methods have been reported in a large variety of domains Currently, contour crafting (CC) seems to be the only layer fabrication technology that is uniquely applicable to construction of large structures such as houses. The goal of Contour Crafting technology is to build custom-designed houses in a short time such as a day. Contour Crafting has the potential for immediate application in low-income housing and emergency shelter construction. The CC method will be capable of completing the construction of an entire house in a matter of few hours.

Contour Crafting is an extended form of 3 D printing technology which can also be referred to as assistive manufacturing or layered manufacturing. in this process three-dimensional shape or electronic data source is used. successive layers of materials are laid as per the computer control.

Additive manufacturing technique came into existence in 1984 but 3D printing technology became popular in 2012 with recent advancements. Recently the 3D printing technology have become a topic of discussion in construction industry, 3D printers capable of printing entire houses in hours have come up this technique is named as ‘Contour crafting’ by researchers

**2.Contour crafting process**

The process of contour crafting typically involves the following steps:

***2.1. Design***: The structure is first designed using Computer-Aided Design (CAD) software.

***2. 2. Robotic Arm Setup***: A large-scale robotic arm is set up and calibrated for the specific contour crafting project. The arm is equipped with an extrusion system that can deposit the construction material.

***2.3. Material Preparation***: The construction material, such as concrete, is prepared by mixing it with additives to ensure proper flow and adhesion.

***2.4. Layer-by-Layer Deposition:*** The robotic arm is programmed to move along the predefined path while extruding the construction material. It starts by depositing the first layer of material and then gradually builds up the structure by adding subsequent layers. The arm follows the design specifications to achieve the desired shape and dimensions.

***2.5. Integration of Components***: As the layers are added, the robotic arm can also integrate additional structural elements, such as reinforcement bars or embedded utilities, into the construction.

***2.6. Curing and Finishing***: Once the structure is completed, it needs time to cure and gain strength. Depending on the construction material, curing can take several hours or days. After curing, finishing touches like surface smoothing or painting can be done manually if required.

**3. Properties of materials used:**

Contour crafting material is technically a mixture of motor since it does not contain any large pieces of coarse aggregate compared to traditional concrete. The primary aggregate used in sand which is almost half of total dry mix volume. Its similar to dry volume mixed motor used for plastering or flooring, these fine grained materials are produced differently than regular concrete, thus cannot be produced in same type of factories the main materials are cement which is used as a binding agent, sand which is used as a filler and a list of additives which include 10 to 15 percent of mixed design. They play a leading role in making material suitable for 3D printing.

Many 3D printing or contour crafting companies have developed their own proprietary mixed proportions some are good some had to compromise on features like compressive strain their crack resistance to maintain an extrudable mix design. Properties expected by the materials include short flowability, extrudability, durability and compressive strength.

1. ***Extrudability:***Means the ability of material to extrude out of the print nozzle easily and consistently, the factors which influence extrudability are:
2. ***Viscosity****:* Its the state of being thick sticky and semi fluid consistency due internal friction. Its primarily a function of water dosage, as water is added to dry mix the material will become less viscous and will flow more easily, where as more material is added it becomes more viscous and flow easily, on other hand if less water is added less viscosity. Compared to contour crafting traditional concrete has lower viscosity. Water quantity is maintained to avoid being too viscous. Admixtures like plasticizers and super plasticizers are also used to maintain viscosity. Another factor that effect material viscosity is thixotropy, property by which material becomes less viscous due to applied stress.
3. ***Pumpability:*** Materials ability to be mechanically pumped throughout the system without use of manual labour. For this fully automated solution be achieved the materials must be pumpable both in dry and wet state. The material arrives in site in dry powder state and must be loaded into the mixing system where water can be added to the mixture its essential that the mix remains completely dry while being transported to site and while its being in store and while its being transferred into the mixing machine this because water will cause the mixture to become sticky and quickly harden. Mix is transported in dry state and mixed with water at site and pumped using a pneumatic pump.
4. ***Aggregate Size***: Large aggregate sizes are use in conventional ready-mix concrete and have tendency to bind together and clog in hose lines. These large pieces are difficult to fit the progressive pump which is a device that is used to pump liquid material continuously and reliably throughout the system, this is because cavity pumps transfer liquids by rotating a helical screw rotor inside a rib flexible housing called stator. As helical screw rotates it creates cavities between the rotor and stator which shrink and expand to force the viscous print material through the system at very precise rates. Large aggregates find difficult to pass through this stator as it damages the stator also it can cause inconsistency in print layers. A concrete vibrator are used to avoid air bubbles, fine sand avoid trapping of air bubbles
5. **Short Flow time:** Flow time begins just after the material is mixed with water and it ends once the material has lost its flowability and has become rigid enough to support its own weight and the weight of the next print layer above without slumping or deforming under the force of gravity. The flow time progresses the 3D print material paste increase in viscosity while loosing its plasticity but should still be tacky enough to bind to the previous layer and the infill material fully and completely. Initial setting time begins as the flow time ends because each subsequent layers adds additional weight to the layers below which will deform if the rate of extrusion outpaces the rate of setting. Once the setting time ends curing time begins, the rate of setting time can be controlled by an accelerators. At many times its found that at every 50 degrees Fahrenheit change in temperature the rate of hydration is changed by a factor of two for example and increase in temperature from 50 degrees Fahrenheit to 100 degree Fahrenheit will double the rate of hydration that means 3D printed mortar will take longer time to set and cure in colder temperatures on hot sunny day. Admixtures can be used to used to reduce temperature effect.
6. **Durability:** Curing process take significantly longer, 3D printed mortar will continue to be stronger in life span. 70 percentage of strength is attained in 7 days of curing period and in 28 days period approximately 80% compressive strength is achieved. Curing is defined as providing adequate moisture temperature in time to allow the material to achieve the desired properties for its intended use. Properly cured concrete has adequate amount of moisture for continued hydration and strength development volume stability resistance to freezing and thawing and abrasion and scaling resistance. The length of curing time depends on five main factors, mixed proportions, specific strain, size and shape of 3D printed members, ambient weather conditions and future exposure conditions.
7. **Compressive strength:** extruded wall samples are used to test the compressive strength. Three point flexural tests are also conducted to ensure that the 3 D printed layers completely adhere and bind to each other so that cold joints are avoided. Cold joints is plane of weakness in concrete caused by an interruption or delay in concreting operations.

Printing

**Fig 2.1 CC process methodology**

**4.Challenges of Contour crafting technology:**

***4.1 Material Limitations:*** One challenge is the limited availability of suitable construction materials that can be used in contour crafting. Currently, contour crafting primarily relies on concrete, but expanding the range of compatible materials could offer more design possibilities and structural options.

***4.2. Structural Integrity***: Ensuring the structural integrity of contour-crafted buildings is crucial. Building codes and regulations must be followed to guarantee that structures meet safety standards. Extensive testing and validation processes are needed to demonstrate the reliability and durability of contour-crafted buildings.

***4.3 Automation and Robotics***: Contour crafting heavily relies on automation and robotics to carry out the construction process. Challenges in this area include developing sophisticated robotic systems that can accurately deposit materials and adapt to different designs, as well as integrating them seamlessly into construction workflows.

***4.4. Cost-effectiveness and Scalability***: While the potential for cost savings with contour crafting is significant, initial setup costs can be high. The technology requires specialized equipment and training, which can be a barrier to widespread adoption. Additionally, ensuring that contour crafting can be scaled up to accommodate large-scale construction projects is an important challenge to overcome.

***4.5. Acceptance and Education***: Introducing a disruptive technology like contour crafting to the construction industry requires education, training, and acceptance from professionals in the field. Building trust and highlighting the benefits of contour crafting are essential for successful adoption.

Addressing these challenges will pave the way for the wider implementation of contour crafting technology in the construction industry, ultimately revolutionizing the way buildings are designed and constructed.

**5.Potential Solution:**

There are several potential solutions to address the challenges of contour crafting technology:

***5.1. Research and Development***: Continued research and development efforts can focus on finding alternative construction materials that are compatible with contour crafting technology. This may include experimenting with different types of concrete mixes or exploring other materials like clay or fiber-reinforced polymers.

***5.2. Structural Testing and Validation***: Conducting extensive structural testing and validation is crucial to ensure that contour-crafted buildings meet safety standards. This can involve collaborating with regulatory bodies and industry experts to establish guidelines and certifications specific to contour crafting.

***5.3. Advancements in Automation and Robotics:*** Investing in advancements in automation and robotics can help overcome the challenges associated with accuracy and adaptability. This may involve developing more sophisticated robotic systems with better precision, sensor capabilities, and adaptability to various design complexities.

***5.4. Cost Reduction Efforts:*** Exploring cost-effective alternatives in equipment, materials, and construction processes can help reduce the initial setup costs of contour crafting technology. This may require collaborations with manufacturers, suppliers, and industry stakeholders to identify cost-effective solutions.

***5.5. Training and Education:*** Providing comprehensive training and educational programs for construction professionals can accelerate the adoption and acceptance of contour crafting technology. This can involve partnerships with universities, vocational schools, and industry associations to develop specialized training programs.

***5.6. Demonstrating Success and Case Studies:*** Showcasing successful projects and case studies that have utilized contour crafting can help build trust and confidence in the technology. This can be achieved through collaborations with architects, engineers, and developers to promote real-world applications of contour crafting.

By implementing these potential solutions, the challenges of contour crafting technology can be overcome, leading to wider adoption and transformation in the construction industry.

**6.Future prospects and Application of Contour Crafting Technology:**

Contour crafting technology holds great potential for the future of construction. Here are some future prospects and potential applications of contour crafting technology:

***6.1. Affordable Housing:*** Contour crafting has the potential to revolutionize the construction of affordable housing. It can significantly reduce construction costs and timelines, making housing more accessible and affordable for a larger population.

***6.2. Disaster Relief***: Contour crafting can play a critical role in post-disaster relief efforts. Its ability to rapidly construct safe and durable structures can provide shelter for affected individuals and communities quickly.

***6.3. Space Exploration***: Contour crafting technology can be utilized in space exploration missions. Building structures or habitats on other planets or celestial bodies using locally available resources could be a cost-effective and sustainable approach.

***6.4. Customizable Architecture***: Contour crafting allows for intricate designs and customization. Architects and designers can leverage this technology to create complex and unique structures that were previously challenging to build using traditional construction methods.

***6.5. Infrastructure Development***: Contour crafting can aid in the development of infrastructure projects such as bridges, dams, and tunnels. Its ability to construct large-scale structures with precision and efficiency can greatly improve infrastructure development.

***6.6. Sustainable Construction***: Contour crafting has the potential to contribute to sustainable construction practices. It enables the use of environmentally friendly materials, reduces waste, and optimizes energy consumption during the construction process.

***6.7. Social Impact***: The adoption of contour crafting technology can have a positive social impact by creating job opportunities and upskilling workers in the construction industry. It can also help address the global housing crisis and improve living conditions for many people.

As technology continues to advance and challenges are addressed, the future of contour crafting looks promising. It has the potential to transform the construction industry, making it more efficient, affordable, and sustainable.

**7. Conclusion**

In conclusion, contour crafting technology shows great promise for the future of construction. However, there are also challenges that need to be overcome.

Some of the challenges include the need for further research and development to optimize the technology, ensuring the safety and durability of the constructed structures, and addressing any regulatory and legal considerations associated with its implementation.

Despite these challenges, the prospects for contour crafting technology are exciting. It has the potential to revolutionize the construction industry by making it more efficient, cost-effective, customizable, and sustainable. From affordable housing to disaster relief efforts, space exploration to infrastructure development, contour crafting has the ability to shape the future of construction in a positive way.

As technology advances, and with continued innovation and collaboration, we can expect to see further advancements in contour crafting technology and its widespread adoption. It has the potential to transform the way we build and create a brighter future for the construction industry.

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