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RESEARCH ARTICLE

EMERGING TECHNOLOGIES AND AUTOMATION IN CONSTRUCTION: APPLICATION TO A TWO-STOREY BUILDING

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Abstract

Construction automation represents a major advance in the architecture, engineering, and construction (AEC) sector. It relies on the integration of technologies such as artificial intelligence, 3D printing, robotics, and drones to optimise costs, safety, and execution times. This study examines the contributions of these technologies, with a focus on 3D modelling and printing of a two-storey building. The methodology is based on a review of the literature and experimental modelling using AutoCAD and Ultimaker Cura software. The results show that 3D printing reduces waste,speeds up construction,and enhances sustainabili ty, while transforming traditional practices. The study also highlights the challenges associated with labour shortages and the need for new skills in the sector.

Introduction:-

In the Architecture, Engineering, and Construction (AEC) sector, construction automation is the use of advanced technologies (generative artificial intelligence, 3D printing, and even drones). By using various technologies, automation aims to reduce costs and ensure safety [1]. By streamlining the various stages of construction, it also seeks to minimise conflicts and improve efficiency [1]. It was in the 1990s that automation and robotics activities and applications began in the construction sector [2].These applications aim to improve safety, optimise equipment operation, and guarantee a high- quality space or environment for building occupants [2]. The adoption of new technologies in the construction sector is essential to remain competitive. "Automation reduces errors and the time spent on tedious and repetitive modelling tasks. The construction sector is shifting towards sustainability and environmental friendliness thanks to automated processes that include improved estimation, optimised use of materials, shorter schedules, and reduced waste" [3]. In addition, the design process is giving way to construction automation and the ability to share data in the BIM model to facilitate better collaboration between teams and save time [3].With the evolution of the construction sector, it is necessary to adopt new technologies to remain competitive. In China, the construction of a hospital that took 10 days to build enabled the first groups of patients to be admitted, to relieve the pressure on overburdened facilities due to the COVID-19 pandemic [4]. To meet the demand for construction projects, robotics and automation technologies are being used to provide solutions to problems related to labour shortages. They also play a role in addressing safety risks, particularly for high-rise buildings [5].The study

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aims to propose a design for a two-storey building, which will then be 3D printed to estimate the cost, completion time, and safety.

Materials and Methods:-

The methodology is based on a review of the literature. Modelling will be carried out using the AUTOCAD software, which is a CAD and CAM application. It can be used for two- dimensional (2D) and three-dimensional (3D) drawing and for calculating summary measurements. The prototype will be produced on a CREATLY printer, using the ULTIMAKER CURA software, which is a 3D printing application.

The design:-

The proposed design is based on a one-storey building model. Figure 2.1 illustrates this model.

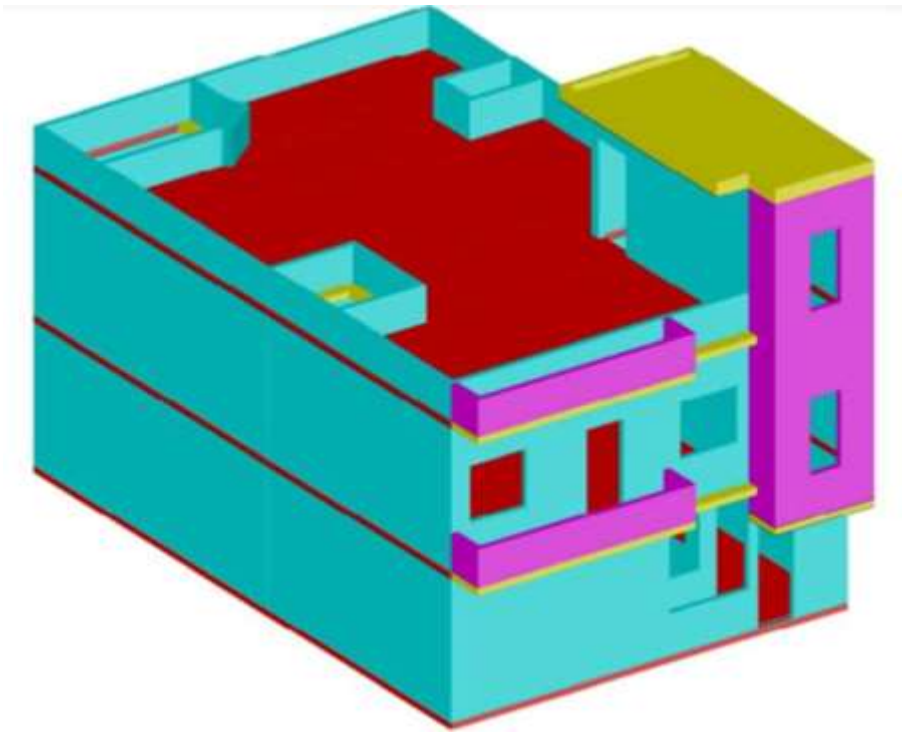


Figure 1: 3D design of the two-storey building

3D printing:-

In the construction industry, printing technology appears to be promising. However, its adoption has yet to become widespread in this sector. Nowadays, 3D printing is becoming increasingly essential in design and construction processes."The 3D printing process uses digital models to create physical 3D objects by layering thin layers of material until the entire object is created. 3D printing technology, which involves the layer-by-layer fabrication of 3D structures from computer-aided design (CAD) drawings, has established itself as an innovative and versatile technology platform. It offers promising opportunities for companies seeking to improve their production efficiency and allows for the printing of various materials, including thermoplastics, ceramics, graphene-based materials, and metals. The adoption of 3D printing technology has the potential to revolutionise industries, enabling faster production and reduced costs. In addition, it gives consumers greater influence over the final product, leading to customised specifications. Extrudability is the ability of concrete to flow through the nozzle. It is assessed based on the concrete paste that can be printed without clogging the nozzle. In addition, the printed concrete paste must be free of cracks and separation. Extrudability depends on the characteristics of the mixture and the calibration of the nozzle. Incorrect nozzle calibration affects the printing of the concrete and can block the concrete in the pump tube. The setting of concrete is a function of time [6].Unlike traditional on-site construction methods, 3D printing reduces waste generated during construction. The use of only the necessary quantities of sustainable and recyclable materials offers greater precision. This is what makes the process more sustainable. 3D printing has the potential to revolutionise architectural design and functionality.

Chronological analysis:-

3D printed construction can be considered an additive, layer-by-layer construction method that produces three-dimensional (3D) objects from a digital file. It offers the opportunity to reduce material consumption, decrease labour requirements, shorten construction times, optimise design, minimise logistical requirements, improve sustainability and reduce costs compared to conventional construction [7]. This interdisciplinary practice draws on knowledge from materials science, mechanics, software engineering, and structural architecture. The figure illustrates the growth of research on 3D printed construction between 1998 and 2019.

Figure 2: Growth in research on 3D printed construction between 1998 and 2019 [7].

Advantages:-

Advances in large-scale 3D printers are enabling the creation of full-scale structures in printed concrete, such as commercial buildings and mass-produced houses."In 2016, a Russian company built the first printed concrete house in just 24 hours. A Russian start-up managed to build an entire house from a single block in 24 hours in the snow using a mega 3D printer. The aim is to keep costs down and provide homeowners with a roof over their heads for less than £7,000. Finally, on 29 March 2014, the Shanghai-based company WinSun Decoration achieved the feat of producing 10 houses measuring 200 m² in 24 hours using a new 3D printing technique, for less than £4,500 per unit. [8]. Similarly, a robotic bricklayer can lay 6,000 bricks per day, while also improving workplace safety. However, a human bricklayer is often limited to laying 500 bricks per day. [9]

Figure 3: 3D printing technique [8]

There are numerous advantages associated with 3D printing construction. However, attention can be focused on the most notable ones, such as:

- The ability to create complex designs
- Customisation and design flexibility
- Efficient use of materials
- The speed and efficiency of the construction process
- Contribution to environmental protection
- Improved safety and quality control
- Sustainability and reduction of environmental impact
- Innovation in the construction industry
- Time and money savings
- More sustainable and environmentally friendly practices

3D printed construction:-

It has been found that 3D printing can significantly reduce the number of workers required, which could solve the problem of labour shortages, particularly in countries where construction relies heavily on immigrant labour. On the other hand, 3D printing could be disadvantageous in countries where construction is one of the main sources of employment and where labour is less expensive. In addition, 3D construction printing will also require people with specific skills related to this new technology [10]. Figure 1 compares conventional construction processes with 3D construc tion.

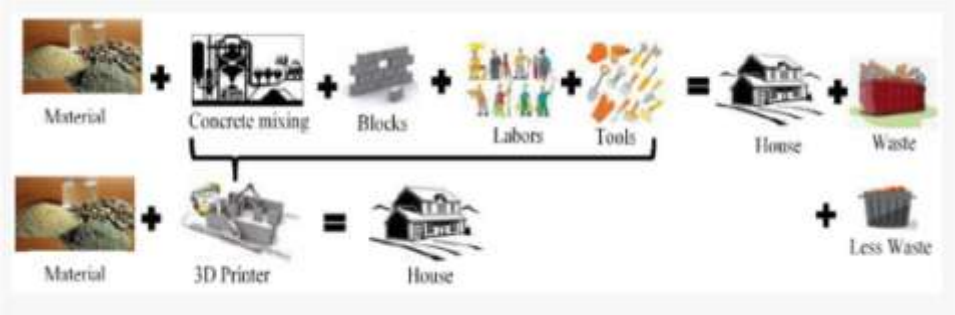


Figure 4: Comparison of conventional construction processes with 3D construction [10]

Method and experimental study (model):-

The 2D and 3D design of the two-storey building is carried out using AUTOCAD software, which is then converted into STL format so that the COURA ULTIMAKER software can read the file format.Figure 4.1 clearly illustrates a print model on COURA ULTIMAKER

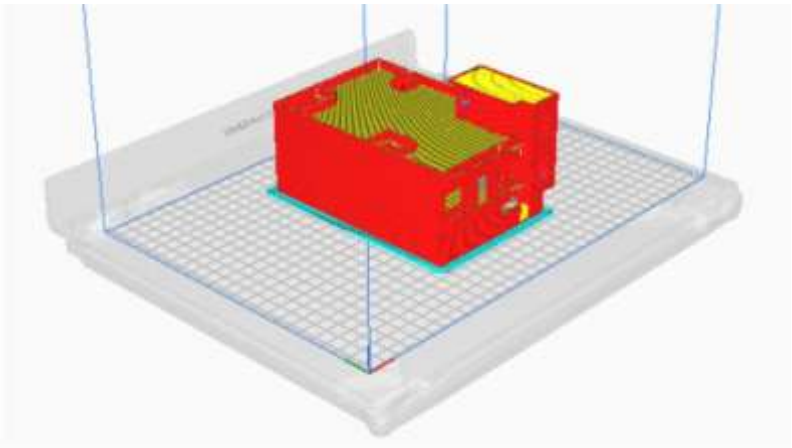


Figure 4.1: Printing the two-storey building on CURA ULTIMAKER

Modelling automated systems in construction:-

An automated system can be modelled in different ways. We distinguish between the algebraic form (logical equation), the tabulated form (truth table) and the symbolic form (logical diagram). In this study, the focus will be on representation using a GRAFCET (Graphical Automated Reasoning Function-Based Control) type logical diagram.

Initial step:

- Filament positioned in the hot chamber
- Digital design entered the printer
- All motors at rest
- Nozzle open [15]

Receptivity:

- I = machine ignition switch. Takes the value 1 if ON and 0 if OFF
- T1 takes the value 1 when the temperature of the heating chamber is greater than or equal to the melting temperature of the filament and takes the value 0 otherwise.
- T2 takes the value 1 when the solid filament is in the melting chamber and the value 0 otherwise.
- T3 takes the value 1 when the filament becomes liquid and 0 when it is solid. [15]

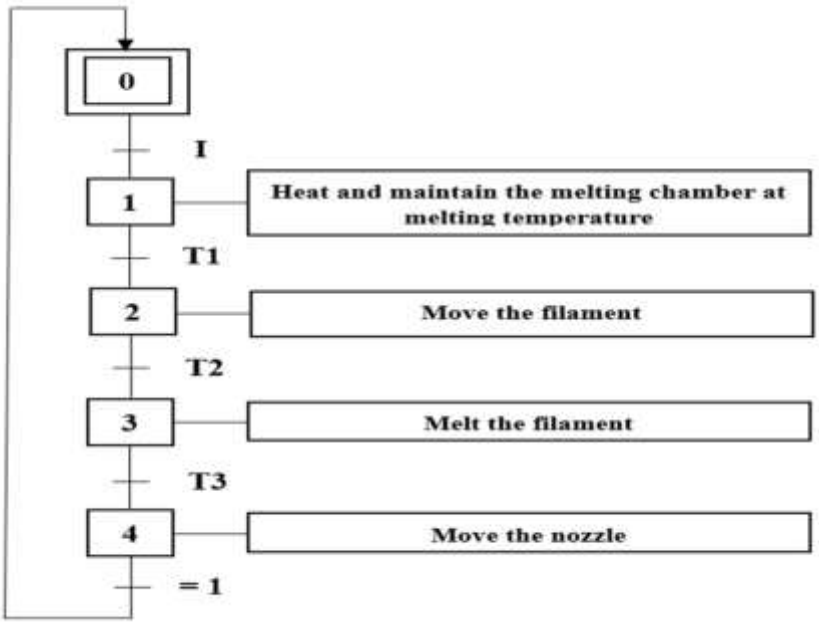
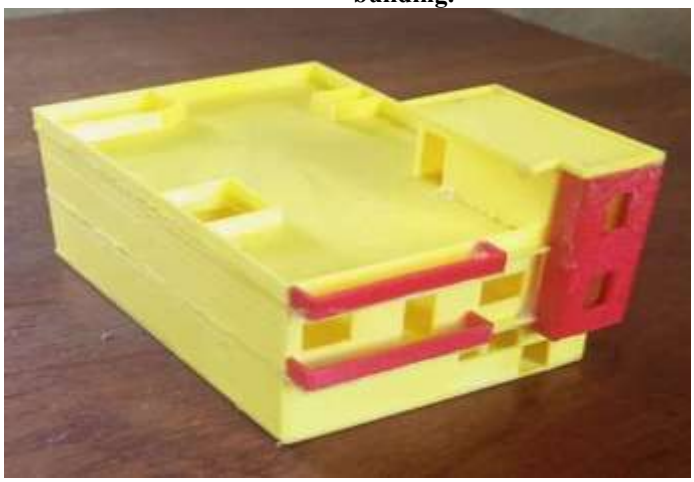


Figure: GRAFCET system view of a 3D printer [15] The results highlighted the 3D printing of a two-storey building.



Conclusion:-

Automation applied to the construction sector is profoundly transforming traditional methods. 3D printing makes it possible to design and build complex structures with unrivalled precision and speed. The main benefits identified are reduced lead times and costs, less waste and human error, and improved sustainability and safety. However, this transition requires skills adaptation and regulatory changes to support new construction practices. In the future, the convergence of robotisation, artificial intelligence, and additive manufacturing promises smarter, more sustainable, and eco-efficient construction.

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