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ROLE OF 3D PRINTED GREEN WALLS IN HEALING ARCHITECTURE

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ROLE OF 3D PRINTED GREEN WALLS IN HEALING ARCHITECTURE

Abstract

Three-dimensional (3D) printing has become a fundamental issue in modern global technology, touching practically every element of modern human life.Three-dimensional (3D) printing (also known as additive manufacturing) is an advanced manufacturing technology that can autonomously manufacture complicated shape geometries from a 3D computer-aided design model without the use of equipment or fixtures.However, there is a friction between traditional designs and the rise of 3D printed technology when it comes to architectural healing approaches, and this adaptability is hurting human healing tactics that are dependent on the relationship between space and environment.Due to its capacity to create products in a wide range of materials rapidly and at a lower cost, additive manufacturing is having a significant impact on production in a variety of areas. Even though it encompasses a wide range of techniques and applications, additive manufacturing (AM) may be described as a system for converting solid model data from a computer-based model into a physical prototype by the incremental addition of material via layer superposition. Therefore, this research aims to examine the 3d printed green walls as new proposed design elements that can upgrade the natural healing architecture. To achieve this goal, the study begins with a literature review that includes scientific methodology based on principles that assist architects dealing with advanced tools in transforming their intentions from digital to analogue means as part of a controlled system intended to innovate design and construction principles of the use of 3D printed green walls. It will also assist in the quest for a concept design that confronts the regeneration of a new spatial delineation ideology.

Keywords

Third Dimensional Printing, Green Wall, Technology, Computer-aided design, Digital construction, Automation, Building materials, Architecture design, Healing Architecture.

1. INTRODUCTION

The goal of architecture is to create something fresh and attractive. Developing a visual concept begins in the mind. Designers may use 3D printing to swiftly create a model using a 3D printer. Physical items outperform computerized ones. Start physically producing your ideas after you've modeled them. Green walls and other architectural ideas may be swiftly created with 3D printing. 3D printing is poised to reshape the creative design sector by assisting designers and engineers in turning their computational dreams into reality(Kidwell, J. (2017)). It is assisting architects in creating healing places with green elements and materials. As a result, the problem attempted is that the architectural healing spatial composition has been subjected to various compositions, thus the need for using modern technological such as 3D printed green wall designs is an additive value to the design, that helps enhancing the creation of green spaces that plays a larger role as an environmental element needed to improve the healing space (K. F. (2017)).

Fig. (1) The world's first 3D printed green with embedded drainage

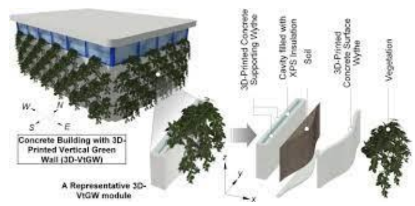

Fig. (2) building with integrated living wall

Source: He, Y., Zhang, Y., Zhang, C., & Zhou, H. (2020).

The main aim of this research is:

"Is to examine the 3d printed green walls as new proposed design elements that can upgrade the natural healing architecture."

To achieve this aim, the research will try to reach the following objectives:

- To identify the types of 3D green walls used in architectural design, the areas and proportions, and the relationship of these green walls and spaces
- To understand the needs of the people and their green healing vision of their place.
- To propose possible interventions that could be done in these green walls to create an interaction platform or environmentally friendly space.
- To introduce 3D green wall design solution as a new approach of intervention.

The utilization of 3D green walls in places to build architecturally creative and green healing spaces for user engagement and environmental solutions in a sustainable and ecologically creative manner is a tremendous step toward establishing a futuristic vision of healing spaces, according to this research.

2. LITIRATURE RIVIEW

While 3D printing technology has the potential to be widely employed in healing architecture, architects must examine how it should be used and what its constraints should be. Healing architecture, for example, should not be bound by specific standards and should instead be designed to be reused (Ghaffar S, Corker J and Fan M (2018)).

2.1 Third Dimensional Printed

Walls A growing body of research is being published on third-dimensional printing as a novel technology that is being employed in a variety of fields, including architecture.3D printing, also known as additive manufacturing, has been used in architecture on a variety of scales and for a variety of reasons. The benefits it offered to manufacturing production in industrialized environments made it appropriate for application in specific components or phases of building construction. Even though 3D printing is not widely used in construction, initiatives to introduce it have yielded positive outcomes, such as complicated joint printing and re-usable formwork for concrete or other materials. Charles Hull invented stereolithography, the first commercial fast prototyping process known as 3D printing. The first uses were in R&D laboratories and tool rooms, but today 3D printing possibilities appear to be limitless (Hooper, O. (2020, May 5)).

22 Historical Background Of 3D Printed Walls

3D printing was typically brought to the market in the mid-1980s as a Rapid Prototyping (RP) technique. Charles Hull created the first 3D printer in 1986. RP has found several uses throughout the years in the manufacturing, vehicle, bio engineering, aerospace, food processing, and industrial sectors. Attempts were made as technology advanced to employ RP for construction-related printing. Printing complicated ceramic and concrete components, plastic and nylon fixtures and fittings, and other small-scale building parts was gradually used by the construction industry. In 1997, the first effort at cement-based 3DP was produced (Agenda, 2017). 3D printing was used to make architectural models in the 2000s. With the improvement of technology over the next decade, building 3DP made its way into small-scale printing. With the improvement of technology over the next decade, construction 3DP made its way into printing complete small-scale structures. R&D efforts are currently being directed at large-scale building printing, with the goal of lowering printing time for structural components while boosting print accuracy. (He, Y., Zhang, Y., Zhang, C., & Zhou, H. (2020)).

2.3 Printing Technology

For 3D printing in building, five methods have been widely employed. Stereolithography forms and places many layers by using a laser to harden liquid polymer and resins on a perforated substrate. Fused-deposition modeling is a procedure in which the printing head is supplied with elastomer, wax, or metal and then produces several layers. Inkjet powder printing uses a powdered version of the deposited material, polymer, or metal, and is a comparable type of printing head deposition. Following that, the product is oven dried. Selective laser/heating sintering also use powdered printing material, often nylon-based, quick steel, or sand form, with each layer solidified using a laser beam. Contour crafting technique deposits ceramic or concrete material (Wu) using a computer-controlled gantry system and a nozzle. (Borshchev, A. (2013)).

Types of 3D Printed Walls

The phrase 3D printing refers to a group of industrial processes that manufacture parts layer by layer. Each method of forming plastic and metal pieces differs, as do material choices, surface polish, durability, production speed and cost. There are several types of 3D printing, which include:

- Stereolithography (SLA)
- Selective Laser Sintering (SLS)
- Fused Deposition Modeling (FDM)
- Digital Light Process (DLP)
- Multi Jet Fusion (MJF)
- PolyJet
- Direct Metal Laser Sintering (DMLS)
- Electron Beam Melting (EBM)

Choosing the best 3D printing technique for your application necessitates a grasp of each process's strengths and shortcomings, as well as matching those characteristics to your product development requirements. Let’s start by talking about how 3D printing fits into the product development cycle, and then we'll look at the many types of 3D printing technology and their benefits.(Crawley, D. B., Hand, Kummert, and Griffith. (2005)).

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2.4 Timeline of 3D Printing

Although 3D printing appears to be a new breakthrough, thanks to the increasing availability of low-cost hobby printers and high-profile 3D printing achievements in medical science, it has been present for decades, as have many other technologies. (Borshchev, A. (2013)).

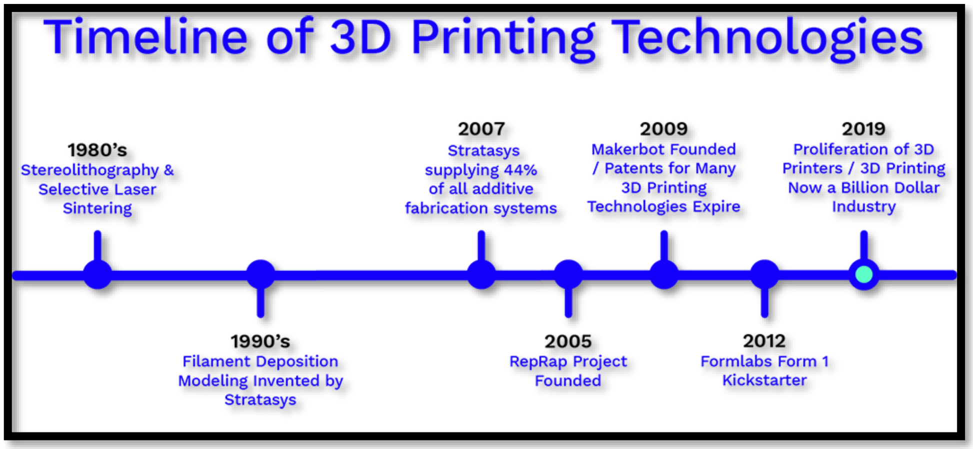

Fig. (3) A Timeline of 3D printing technology

2.5 Green Walls

Green walls are made up of plants growing in vertically supported systems that are often attached to either interior or exterior walls; although, in extreme circumstances, they can be self-supporting. Green roofs, like many green walls, combine and integrate growth medium, vegetation, irrigation mechanism, and drainage into a unified system. Living walls vary from green facades in that they include several plantings to produce vegetative cover rather than relying on fewer plants that climb and spread to give cover. They are also known as vertical gardens or bio-walls. While a green façade in the form of a building envelope is related with a climbing plant, a living wall is comprised of a building envelope coupled with a system including growth medium and a plant. (Lally, S., & Young, J. (2007))

2.6 Historical Background of Green Walls

A green wall is a wall that is partially or entirely covered in vegetation and contains a growth media, such as soil. Most green walls also include a built-in water supply system. Green walls, also known as living walls or vertical gardens, are a type of green wall (Wikipedia.com, 2010). The first green wall was proposed during the Viking age in the 11th century. The Vikings built their homes out of stones, lumber, and peat bricks. Peat is an accumulation of partially decomposed plant materials that forms in marshes or other similar environments. Grass grew organically on peat's brick when the Vikings used it as a building material. The settlement was completely engulfed in jungle. The grass roots assisted in the joining of the bricks into one large brick, making the walls sturdier. Wherever the Vikings travelled in the north hemisphere, such structures could be found from Canada to Norway, via Ireland, Sweden, and Denmark. (Law, A. (2014)).

2.7 History of Green Walls

The notion of green walls is an ancient one, with instances dating back to the Babylonians - with the famed Hanging Gardens of Babylon, one of the world's seven ancient wonders. Highlights of the history of green walls are provided below:

- From the third century BCE until the seventeenth century AD, Romans trained grape vines (Vitis species) on garden trellises and villa walls around the Mediterranean.
- Climbing roses on manors and castles are symbolic of secret gardens.

- 920s: The garden city movement in the United Kingdom and North America promotes the integration of house and garden through elements like as pergolas, trellis constructions, and self-clinging climbing plants.
- 1988: The first stainless-steel cable system for green facades is introduced.
- The early 1990s see the introduction of cable and wire-rope net systems, as well as modular trellis panel systems, to the North American market.
- 1993: The first major use of a trellis panel system is at Universal City Walk in California.
- 1994: Installation of an indoor living wall with a bio-filtration system at the Canada Life Building in Toronto, Canada.
- 2002: The MFO Park, a multi-tiered park structure 300' long and 50' high, opens in Zurich, Switzerland.
- Over 1,300 climbing plants were used in the project.
- 2005: The Japanese federal government financed a large Bio Lung display, which was the focal point of Expo .
- 2005 in Aichi, Japan. The wall is made up of 30 various modular green wall systems that may be found across Japan.
- 2007: The Green Factor, which incorporates green walls, is implemented in Seattle.
- 2007: GRHC offers the first full-day Green Wall Design 101 course in North America.
- 2008: The Green Wall Heritage Center establishes the Green Wall Award of Excellence and the Green Wall Research Fund. (Law, A. (2014)).

Fig. (4) Ivy attaches to a building using aggressive adhesive suckers or climbing roots that can damage surfaces and enter voids and cracks.

2.8 Types Of Green Wall Living

Walls, direct green walls, and indirect green walls are the three basic forms of green walls

- Living walls are a more recent design trend.
- They are made up of plants that are housed in artificial substrates.
- Living walls are a newer design option. They are made up of plants that are housed in artificial substrates. Irrigation and nutrient diffusion are accomplished through the use of hydroponic technology. There are many different types of living wall systems on the market, including in-situ living wall panels, prefabricated living walls, foam-based systems, and planter box systems .
- Clinging climbers—plants with adventitious roots and sticky disk tendrils—are used to form a vegetative surface on direct green walls . Vines are also used in indirect green walls.
- Climbing vines such as twining plants, leaf climbers, and tendril bearers are used in these systems to offer independent structures to support the vegetative canopy . (Kidwell, J. (2017)).

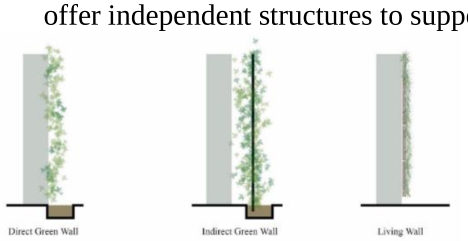

Fig. (5) Diagrammatic representation of green facades and the canopy relation to a building façade

2.9 Combination Of 3d Printing and Green Walls

The world's first fully 3D printed, irrigated green wall with an inbuilt water supply and drainage system is the BANYON ECO WALL by bigrep. The invention is made feasible by barge's use of the world's largest serial production 3D printers (FFF). NOWLAB, a bigger Innovation Consultancy, has created the concept to date. A drainage system is required for any irrigated green wall to work properly. Until date, 3D printed green walls either depended on later-integrated (metal) drainage systems or were based on elaborate set-ups including several elements. The drainage system in this case is incorporated and formed during the printing process. (Kidwell, J. (2017)).

Fig. (6) The world first green 3D printed wall

2.10 The use of 3D Printed Green Walls as elements in the healing architecture

Several scientists and a few renowned publications have led attempts to quantify "the environmental effect of health care...to estimate the potential benefit of mitigation initiatives and to prevent damage associated with health care delivery." The purpose of this article is to offer background information on the incorporation of environmental ethics into health care. I'll go through a quick history of the field in chronological order. Van Rensselaer Potter's first book, Bioethics: Bridge to the Future, extended medical ethics themes, such as accountability and rational conduct, to other areas of life, such as ecology. Potter considered the interdependence of human life and nature as self-evident, given that we humans live in a natural environment, and aimed to link us not only to health within the hospital, but also to holistic existence in the world. He released his second and final book, Global Bioethics: Building on the Leopold Legacy, in 1988. Global Bioethics aims to reconnect the medical sector with its earthly roots. Even though medicine was created by and for humans, we have come to rule "nature" rather than coexist with it .(Mills, C. B. (2000)).

Potter laments in the first few pages that "with the concentration on medical solutions, many forget that bioethics had been presented to unite human values with ecological realities." Potter believed that the survival of the species was critical, but he also recognized that there was a "ecological need to limit the exponential increase in the human population... no program [of conservation or advancement] can hope to succeed without the acceptance of controlled human fertility as a basic ethical imperative for the human species." Potter's work situates bioethics in the bios—life in the world—and establishes a link between medicine and conservation. His seminal publications paved the way for multifaceted advancement in environmental bioethics in the years that followed. (UCF, (2014).)

2.11Examples of Application

Many structures are designed around important spatial forms, codes, utility, materials, and identity.The architectural design's conceptual consequence of the green 3d printed wall:

Green Walls Examples(Outdoor and Indoor)

Fig. (7) Grid system, Ex Ducati Office, İtaly

Fig. (8) Grid and wire-rope net systems, MFO Park, Switzerland

3D Printed Walls Example of Application

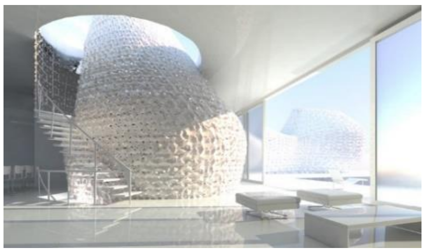

Fig. (9) A feature wall created with technology

Fig. (10) VULCAN, architectural pavilion 3D printing Edg's printed for Beijing Design Week back in 2015 Park, Switzerland

Fig. (11) A feature 3D Printed Living Structures in the Pompidou

2.12 Parameters of Analysis

Based on analyzing and understanding both 3D printing technology and green walls in architecture design, and after the creation of new trend in 3D Green Walls printing , these parameters are depicted as prompt to be discussed throughout the paper; to distinguish the language that should be incorporated as a new approach design to revive dystopian paranoid sites.

Table (1) Parameters of Analysis

Parameters of Analysis	**Means**
Physical Dimension	Proportion of intervention to the number of users, allowing the maximum amount of people to interact within the project.
Design approach	• Exterior and entrance design • Interior Design Elements and Systems
Materiality	Materials that complement the theme of the project
Environment	Climatic changes and Environmental Goals
Target Audience	Activity and Productivity of the users

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2 METHODOLOGY

Various forms of research methods are employed in this work. These are the inductive method, the field method, the analytical method, and the deductive technique.The inductive technique is centered on acquiring facts on the case study, "Jarjouh City." Following that is the field approach, in which the author visits the location in Jarjouh, takes live images and sketches, and conducts a questionnaire for the people on the site or nearby. Later, the analytical technique is used to assess the field method's research and surveys. Finally, in the deductive technique, a strategy and solutions will be given and explored. These methodologies were utilized to assess the case study and develop the goal, which is to investigate 3D printed green walls as new recommended design features that can improve the natural healing architecture in Jarjouh city.

3.1 Introducing the case study of "Jarjouh Healing Resort" south of Lebanon

Jarjouh is located in the oldest occupied area of south Lebanon, and it is a low density area with some of the oldest built houses. This area has grown in a disorganized way, with no neighborhood design initiatives in place. However, this city includes several types of natural views and is known for its touristic characters such as natural tourism for its different topography that is characterized by raw mountain views, where these mountains are rich with trees and with little human intervention in the natural composition of the land. The people that live in this region are low-income, but they also have access to basic leisure amenities, such as religious institutions and restaurants. Excavation work on the site began in 2012, and a new project was scheduled to be built. Since then, the site has been open to the public. People live in the heart of the constructed environment, in a natural composed city, with a site regarded one of the natural sites in Lebanon, even though it is a city that lacks architectural planning, but it is a natural location where visitors go to rest. These natural mountain locations are one of the methods to connect the built environment with a therapeutic facility constructed with respect to green walls to help the healing process in a calming natural urban fabric such as the Jarjouh district.

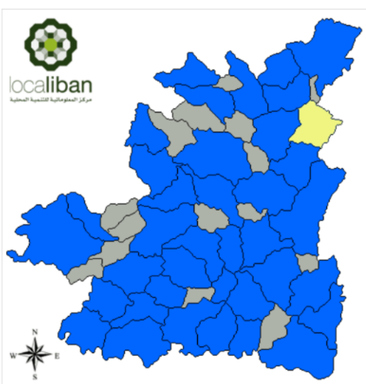

Fig. (12) location of Jarjouh in Nabatiyeh district

3.2 Urban Analysis of Jarjouh

Jarjouh is a village in Lebanon, located in the Nabatieh District, Nabatieh Governorate. between the villages of Houmin Al Fawqa, Arabsalim, Jbaa, Ain Bouswar, Alwayizeh, Soujod, Ain Qana. The village sits on the shoulder of Mleeta hills, with Oak forests on the surrounding mountains. Al Zahrani River spring starts in Jarjouh known as Al Taseh spring. The demography of Jarjouh is approx. 50% Christian and 50% Muslim. Some scholars attribute the origin of this town's name to the Hebrew word meaning "the shaved, the hairless or the bald." Others trace it back to a combination of two root words meaning "drinking and shortage.

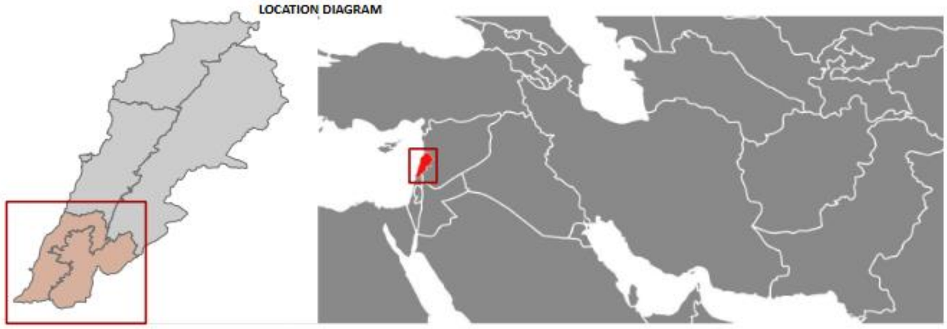

Fig. (13) location of Nabatiyeh district on map

Fig. (14) physical satellite picture showing Jarjouh(Data provided by the Ministry of Environment on 2011)

3.2.1 Population in Jarjouh, Nabatiyeh

The Nabatiye Governorate has around 330,000 residents (including Syrian and Palestinian refugees), making it the governorate with the lowest population share in Lebanon. The population density of Nabaityeh's Caza is roughly 305 persons per km2. The governorate of Nabatiye has a poverty rate that is 25% lower than the national average of 27 percent. Furthermore, the unemployment rate is predicted to be 6.0 percent, lower than the national average of 11.4 percent. According to the Syria Refugee Response per District, the overall number of Syrian refugees in Nabatiye Caza is roughly 21,500. Table 4-5 shows the number of Syrian refugees registered in each of the villages located within the planned project area as of the end of 2019, with a total of 4,177 registered refugees in the project area as of the end of 2019. According to the UNHCR, there are no informal tented camps for migrants in Nabatiyeh Caza. Furthermore, Nabatiye Caza has no Palestinian refugees. (UCF, (2014)).

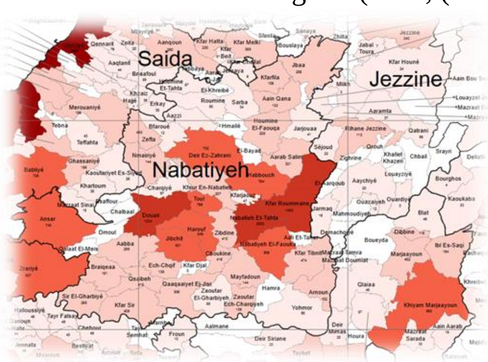

Fig. (15) the map shows the population in Nabatiyeh District and can show the low population in Jarjouh

The labor force is mostly concentrated in the manufacturing (29%) and service (26%) sectors. The wholesale and retail trade sectors account for 60% of Jarjouh's total gross value added. The Nabatieh district has the biggest concentration of industrial enterprises, accounting for 63% of all industries in the governorate.

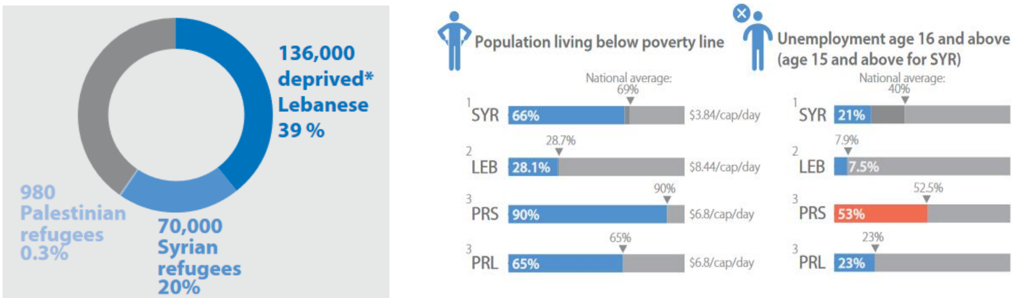

Fig. (16) diagram shows the population and their economical state in Jarjouh

3.2.2 Economic Activities in Jarjouh, Nabatiyeh

Jarjouh's economic activities are centered on commerce, services, and real estate. Jarjouh Village is the major hub of the Caza and serves as the main market for the Caza's communities. Jarjouh is also the Nabatiye governorate's administrative capital. During the site tour, the following stores were discovered:

• Aluminum and metal shop
• Car repair shop
• Pharmacy
• Jarjouh cave
• Restaurant and Café
• Butchery
• Clothing store
• Mini market
• Bookshop
• Flower shop

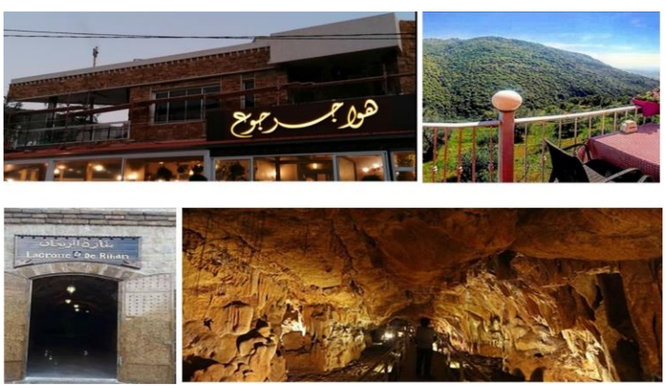

Fig. (17) picture showing Jarjouh touristic places

3.2.3 Cultural Heritage in Jarjouh,

Nabatiyeh During the site visits, sites of archaeological or cultural importance were not identified along the project roads. Moreover, none of the proposed roads led to any archaeological site. However, the caza has some ancient rock tombs, Roman and Byzantine ruins and several old mosques as well as old churches. (UCF, (2014)).

Fig. (18) picture showing Jarjouh mosque and church

3.2.4. Water and Soil Quality in Jarjouh,

Nabatiyeh Contamination of soil, subsurface, and surface water may occur as a result of many actions associated with the planned project's rehabilitation. These include incorrect solid waste and excavated material disposal, improper discharge of liquid waste and wastewater, unintentional oil and chemical spillages, and diversion of polluted rainfall runoff from the project site.

Liquid waste from rehabilitation

- Concrete mixing for retaining walls and sidewalks is a major rehabilitation activity that generates liquid waste.
- Excavation of road sections under severe circumstances that generate runoffs polluted with suspended particles, particularly on rainy days if restoration work begins in the fall season;
- Storm water discharge containing a high concentration of suspended particulates .If not discarded and managed appropriately, this liquid waste might harm surrounding water courses, streams, and soils.

Wastewater

During the restoration of the projected roadways and accompanying works, workers will be required. As a result, employees will create wastewater during the repair process.If the produced wastewater was not managed to be released in appropriate tanks or linked to the existing sewage network, neighboring surface water bodies might be contaminated with significant organic loads, particularly when water was found using Lebanon's hydrological map. (UCF, (2014)).

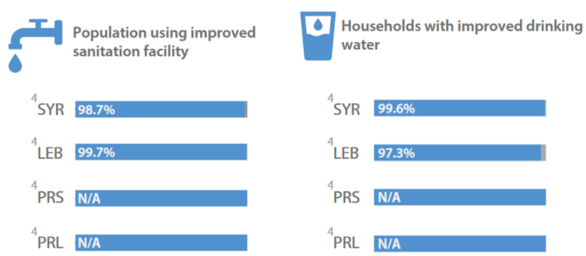

Fig. (19) diagram showing water use in Jarjouh

3.2.5.Air Quality, Noise and Light in Jarjouh

Nabatiyeh During the restoration phase, the machinery and vehicles employed emit air pollutants and gases that might temporarily impair local air quality. In general, particulate matter, Benzene, Toluene, Xylenes, Ozone, Nitrogen Oxides and Sulfur Oxides, Carbon Dioxide, and Carbon Monoxide are present in air emissions produced by the burning of diesel utilized by machines and automobiles. (UCF, (2014)).

3.2.6.Access to Resources in Jarjouh, Nabatiyeh

- The second highest concentration of Lebanon’s olives cultivation accounted for 18%.
- The third highest share of goat farming in all Lebanon.
- Increase of industrial firms at a CAGR of 13% over the 2011-2016 period.
- Food and beverages sector is the largest industrial sector and comprises around 28% of industrial firms.

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3.3. Identifying problems of "Jarjouh Healing Resort" south of Lebanon

Because Jarjouh was not designed according to urban laws and regulations, the neighborhood in Jarjouh does not follow the typical form of a community in any manner. The main difficulty was that Lebanon is suffering a major problem with health care facilities, particularly after Covid -19. When Jarjouh was chosen as a case study for establishing a health care facility, a major issue was discovered. Jarjouh is noted for its beautiful geographic components, but it also has relatively hard topography on which to construct.

Site constraints:

According to the studies, because the project is located on a steep slope, a 25 percent post and beam structure that steps with the site should be adopted. This might include a basement level with a concrete slab. A single slab on the ground should not be utilized. They will take place in the heart of Jarjouh Mountain. They are made of natural materials and are meant to suit all the demands of its visitors while maintaining a fresh and inviting appearance. (UCF, (2014)).

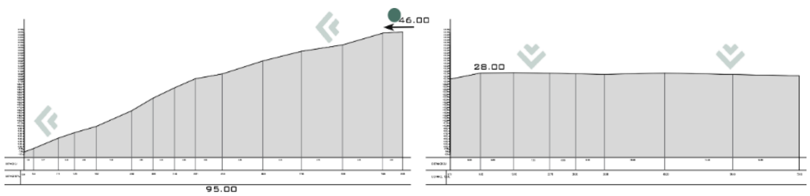

Fig. (02) diagram showing the site section in Jarjouh

Topography

The property is located 860 meters above sea level in a hilly terrain with a steep slope. The topography of the location influences vistas, drainage, and road and pedestrian slopes. The topography of a property may impose significant restrictions on its usage.

3.4 Selection of a Specific Area in Jarjouh

Jarjouh hamlet was chosen to explore the potentials of natural places for a variety of reasons. For starters, the village is located on the southern flank of the Nabatiyeh district, and it is not impacted by the flow of people and traffic to the city center; it is a strategically significant site in Nabatiyeh. Second, the region is one of the oldest portions of Nabatiyeh, and it has far too many tourist attractions, as well as a historical site and other tiny parcels of land. The project's goal is to reinvigorate Jarjouh hamlet and build a link between it and its nearby locations by connecting it to the surrounding cities.

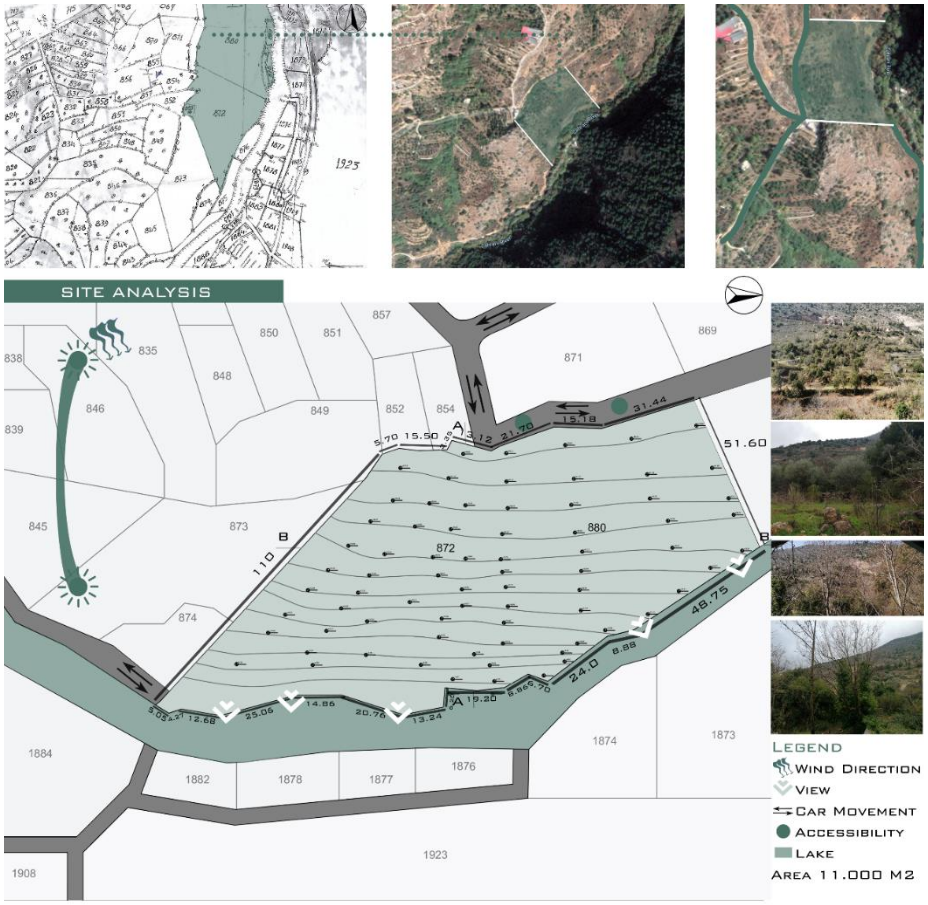

Fig. (21) The selected site in Jarjouh

3.5. Different Opinions Concerning the Green Healing Resort in Jarjouh

In order to gain credibility and have more encounters with people, this study chose to meet with a sample of the general population who live and work in Jarjouh. The research used two sample field methods to arrange the sample's point of view, visions, wants, and recollections. Holding interviews and disseminating a questionnaire form in the manner described below.

3.5.1.Holding interviews

Face to face interviews were made, from 18 to 22 October2021, with 15 elderly people that lived their life in Jarjouh, and they responded a lot of interesting things about the village history. During the interviews, three questions were asked:

- How do you consider your self-belonging to Jarjouh?
- What do you think about creating healing architecture place in Jarjouh that mainly depends on 3D printed green wall?
- How may you consider the proposed project if located in Jarjouh and what do you think about using the village topography as a healing place?

Answers were mostly similar; samples of these answers can be presented through the following quotations:

- Placing modern elements to the project in Jarjouh may help creating a new point of view for the visitors about an old village of south Lebanon

- Any changes in the selected area should be focusing on the resident's needs, to make their daily life better and not transforming it from a low class and quite area into a noise point and disturbing the quite nature of the village

- Strongly agrees about the idea of creating healing architecture place, and how the project will bring money not only for the village municipality, but also all kind of economic activities will be revived through the visitors of the project which will affect the over economic situation of the area.

These opinions are taken into consideration by analyzing and interpreting the results and taking the recommendations into actions.

3.5.2. Questionnaire

A closed questionnaire was designed and distributed on 150 educated and non-educated people found in the village, such as engineers, doctors, sellers, also touristic visitors who were found they're from outside the village, in an age between 25 to 55 years old. This questionnaire was submitted in the village . Questions mentioned in this form were directed, sample, and specific as following:

- What is your opinion about the current medical situation in Lebanon? o What is your vision about having a medical healing resort I Jarjouh?
- On a scale from 1 to 5, how likely do you feel safe and comfortable having medical healing resort adopting 3D printed green walls in Jarjouh?
- How likely do you feel comfortable living in a neighborhood adjacent to a healing place mainly function on 3D printed green wall?
- Do you think that using 3D modeling effect positively on the healing project?
- How likely do you agree upon transforming a place in the mountain of Jarjouh into?

After visiting the site and completing the field methodology, the paper analyzes results and findings of answers.

3.6 Materials, Methods and Experiment Program

This section of the study describes the additive manufacturing process for a scaled-down replica of a wall . The study modifies the wall design and printing method to accommodate for the rheological and mechanical qualities of new concrete while also considering the lintel installation procedure.

3.6.1 3D Printer

The wall, which was constructed using a 3D robot and a pumping module, was created at a carefully selected location. A screw feeder with a nozzle exit diameter of D = 20 mm was used to extrude the mixture. To control the printer's and printing head's motions, a G-code was employed. The combination was created in a laboratory mixer and then carried to the pump unit, where it was pumped through a conduit into the printing head hopper. (Hooper, O. (2020, May 5)).

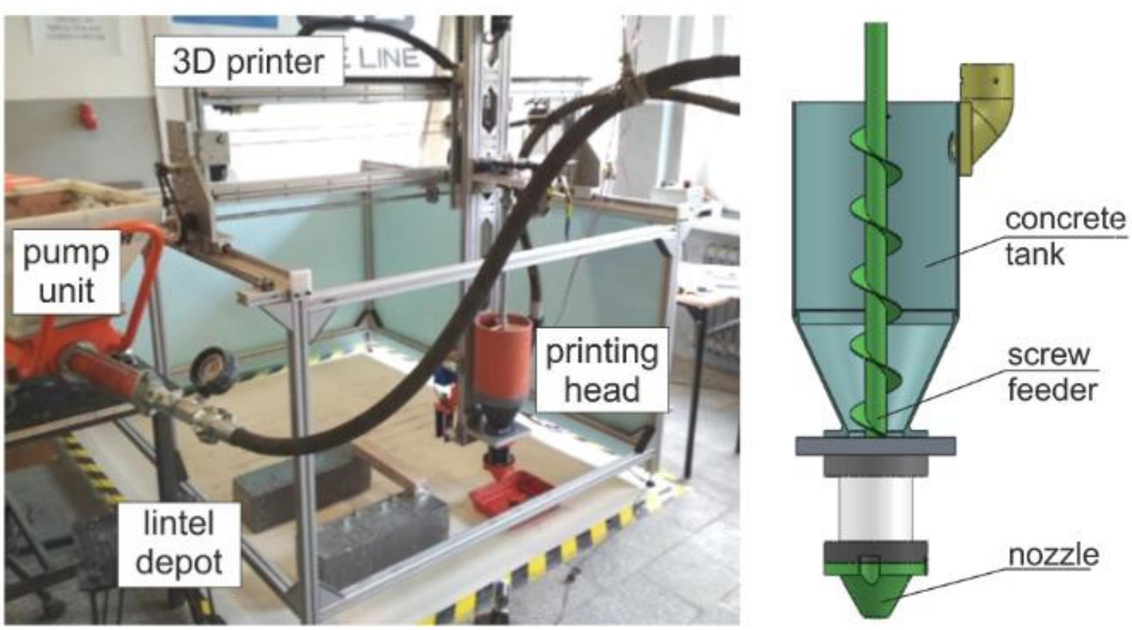

Figure (22). 3D printing set-up: (a) Cartesian robot and pump unit, (b) printing head.

3.6.2 Concrete Characteristic

The concrete is self-compacting (SCC) and has a slump flow property of SF=600mm. The concrete is immediately injected with its composition, allowing it to flow readily into the printed FW without the requirement for vibration. (Mills, C. B. (2000)). The obtained free surface is horizontal. Because the FW is constructed of an insulating material, and because there is a possibility of the concrete's cure temperature being too high, which might result in long-term pathologies and a reduced lifetime of the wall, the concrete is properly regulated with an appropriate set accelerator.(Maria, Anu. (1997)).

3.6.3 Robotics System

The robotic systems or machines evaluated for various 3D building printing trials across the world are based on two fundamental principles: machines in the workshop that pre-manufacture components or machines that construct on site. The bulk of research using large gantry-type machines have been conducted in the context of on-site construction [9-15]. These machines need a significant amount of infrastructure and work, and erecting a gantry machine takes longer than building a house [15, 24].(Tay, Y. W. D., Panda, B., Paul, S. C., Noor Mohamed, N. A., Tan, M. J., & Leong, K. F. (2017)).

3.6.4 Process

By adjusting the isocyanate and polyol flow rates, as well as the nozzle height and displacement speed, it is possible to print a PU wall with a mean width of around 240 to 260mm and a height of about 35mm. To obtain a component of the 3D printed wall to scale 1/500 at least equivalent to 6.75m2.K/W, the minimum thickness of the plastic should be equal to 80mm. A 3D scan of the surface was performed on a 300x300mm2 sample taken from a larger wall.(Gleiniger, A. & Vrachliotis, G. (2008)).

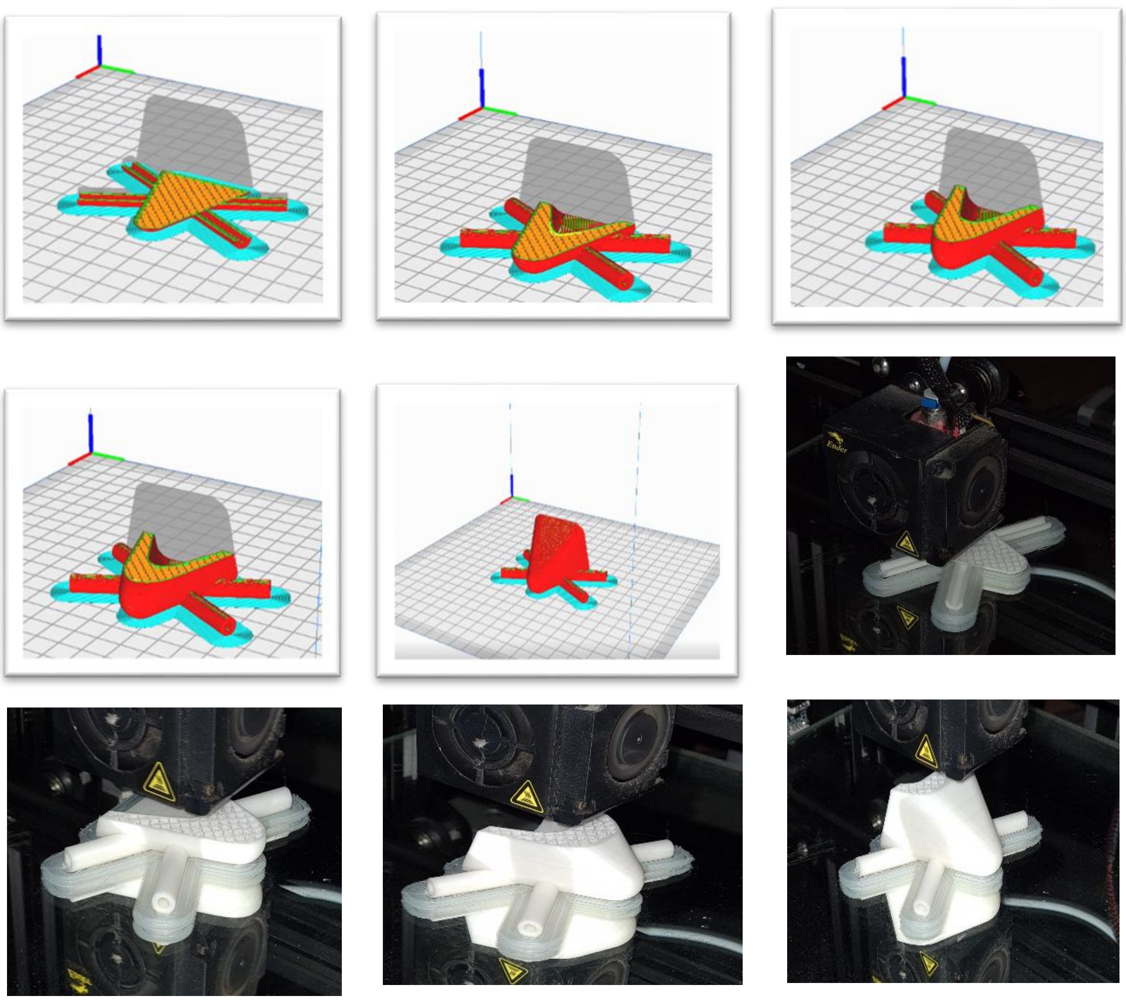

Figure (23). 3D printing layers

3.6.5 Concrete Characteristics

The concrete is self-compacting (SCC) and has a slump flow property of SF=600mm .

- The concrete used in all of the experiments is made up of the following ingredients: - cement CEM III 42.5 - limestone filler
- the beach (0-4mm)
- pebbles (4-10mm)
- water - a predetermined accelerator Because of its nature, the concrete can be pumped into the printed FW instantly without generating vibration . The free surface that results is horizontal . Because the FW is constructed of an insulating material, and there is a possibility that the concrete's cure temperature will be too high, resulting in long-term pathologies and a lower wall life, the concrete is closely regulated using an appropriate set accelerator.(Tay, Y. W. D., Panda, B., Paul, S. C., Noor Mohamed, N. A., Tan, M. J., & Leong, K. F. (2017).).

3.6.6 Results and Discussions of Concrete Analysis

Following the completion of the trials, the data was gathered and presented to show the deformation of the FW acquired in the various experimental tests. Because of the hydrostatic pressure caused by the water, the formwork deforms dramatically during the water filling process. The water level in the formwork determines this pressure . The deformations of the FW were initially set to zero (blank map for a height of 0cm). The deformation maps show that the distortion is small while the water level is low, but it grows as the water level rises. The FW is clearly influenced by the rise in water level, and the deformations occur across the FW. The FW has the highest distortion in the middle due to its symmetric construction. Furthermore, the point of maximum distortion is around 50cm away from the slab. This distortion is 10 mm for a water height of 40 cm, and it may be as high as 25 mm for a water height of 60 cm. The deformations are visible with the naked eye.(Borshchev, A. (2013)).

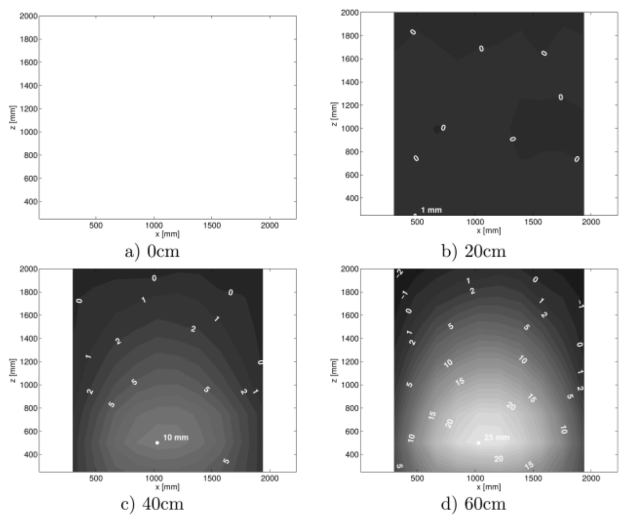

Fig. 24 Deformations of the simple formwork for different heights of water (same color scale) – the numbers on each picture correspond to the deformation of the FW (mm)

The highest distortion obtained for a concrete height of 100cm is 20mm . To minimize failure of the FW on the construction site and considerable material losses, the maximum height of concrete that may be poured into it must be less than 50cm.(He, Y., Zhang, Y., Zhang, C., & Zhou, H. (2020)).

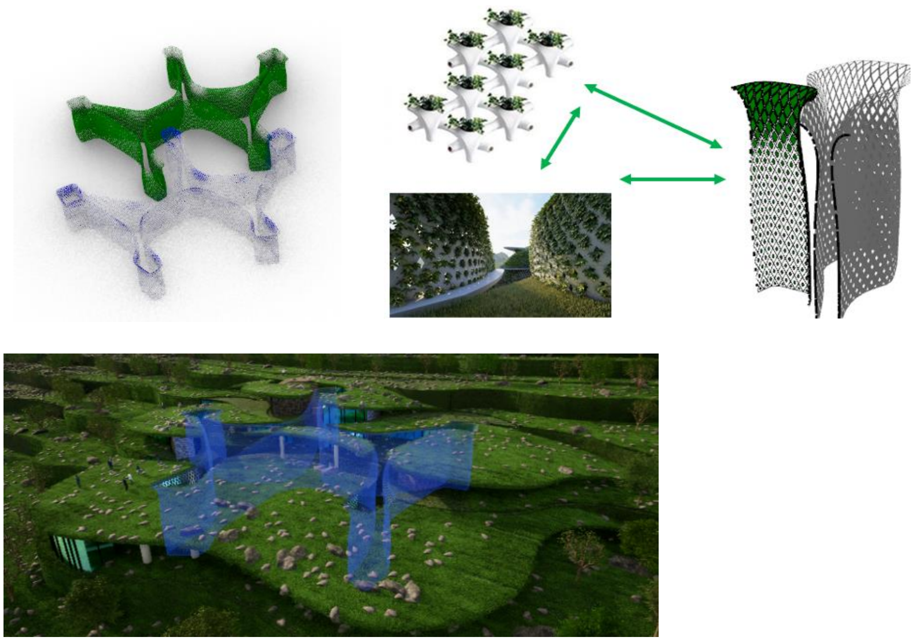

Fig. 25 Application of 3D printed wall in project

4.FINDINGS

After using the analytical methodology, the results of the answers will be presented in a form of charts.

4.1 Analyzing the questionnaire results

To obtain reliable findings, the interviewees' responses were converted into statistical charts. Then it will be turned into the design output to meet the needs and stay on track with the paper's goal. A closed questionnaire was prepared and delivered to 150 educated and uneducated persons located in the village, such as engineers, physicians, vendors, and tourists from outside the hamlet, ranging in age from 25 to 55 years old.

This questionnaire was filled out in the village.

The following questions were included in this form because they were directed, sampled, and specific: 39 of them were uninterested, while 111 responded. SPSS was the statistical application utilized to analyze the results. First, respondents were asked to fill out personal information such as their name, job, and age.The following are the outcomes of the responses:

- Answer of first Question, “What is your opinion about the current medical situation in Lebanon?”

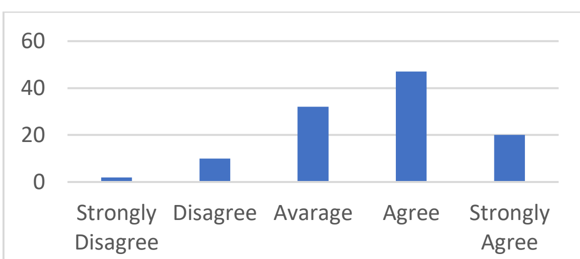

Chart 1: Chart showing the results of the first questioner

- Answer of second Question, “What is your vision about having a medical healing resort in Jarjouh?

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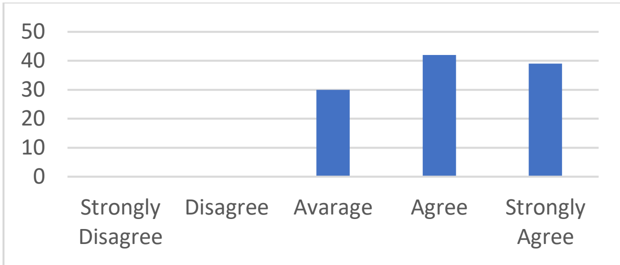

Chart 2: Chart showing the results of the second questioner

- Answer of the third Question, “On a scale from 1 to 5, how likely do you feel safe and comfortable having medical healing resort adopting 3D printed green walls in Jarjouh?”

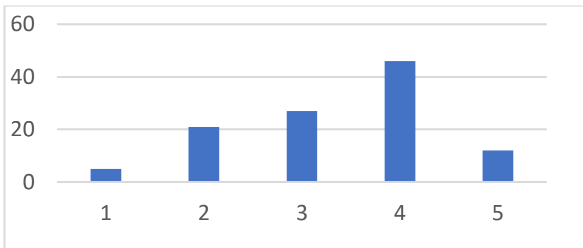

Chart 3: Chart showing the results of the third questioner

- Answer of the fourth Question, “How likely do you feel comfortable living in a neighborhood adjacent to a healing place mainly function on 3D printed green wall?”

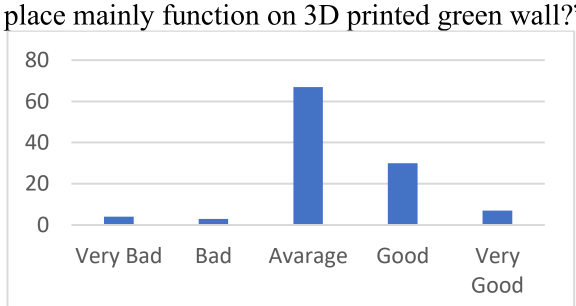

Chart 4: Chart showing the results of the fourth questioner

- Answer of the fifth Question, “Do you think that using 3D modeling effect positively on the healing project?”

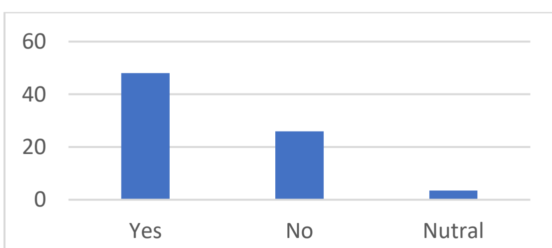

Chart 5: Chart showing the results of the fifth questioner

  - Answer of the sixth Question, “Do you think that using 3D modeling effect positively on the healing project?”

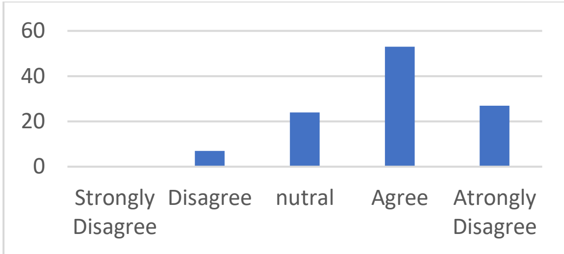

Chart 6: Chart showing the results of the sixth questioner

4.2 Discussion

The main questions answered in this study were about the influence of the digital tool used throughout the manufacturing process on the architectural design process, as well as the identification of the components that typically revolve around this connection. The definite response to the first subject is that the influence is rapidly rising and is becoming increasingly closely tied to the project's formative makeup . In terms of the second theme, the key conclusions were mostly connected to the tool and the material (direct relationship), and that the material becomes the structure itself while the tool manipulates the form depending on its strengths and restrictions.

5.CONCLUSION

Digital fabrication represents a significant shift in how the future architectural age is envisioned. The techniques used by digital fabrication necessitate rethinking the design process, often resulting in the development of novel methodologies and nonlinear approaches. By allowing integration and strategies of creative ideas and manufacturing operations to inform each other in a meaningful way, the potential of this movement can be fully realized.

a) An interest in experimentation and hence study of materiality and how design purpose may be related or represented via their usage is critical to this growth.
b) The use of computational design to construct digital tools has been essential in the recent case studies discussed. Given that these technologies serve as a bridge between design and manufacture, the experimentation and customization they enable should give a plethora of options for academics and architects. The subject provided in this article is a type of knowledge that we thought to be very important, particularly amid the Information Technology revolution that is opening up new possibilities.
c) There are several potential to be investigated in the field of computer science, and our hope is that a speculative approach to working may still introduce substantial external challenges into the design process.
d) We also feel that there may be a link between experimental practice and knowledge within the architectural field, as well as other disciplines that include design in architecture.
e) We believe that a parametric idea based on folding inside a generic theoretical model may be a good beginning point. and such a model might be utilized, changed, and assessed on a continual basis.

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