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CONTEMPORARY BUILDING TECHNICS USING CONVENTIONAL MATERIALS, OF CLAY AND MUD

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Supervisor

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Signature

DEDICATION

I thank God Almighty for helping me and granting me success in completing this thesis.

This thesis is wholeheartedly devoted to my mother, father and my kids. It is impossible for me to put into words how much it means to me. There is absolutely nothing I can do to make up for what you have done to me. I shall keep doing everything in my power to live up to the standards you have set.

In conclusion, I would want to say thank you to my family. They helped me a lot and encouraged me to complete this project.

PREFACE

First of all, I thank Allah Almighty for helping me complete this thesis.

I am pleased to extend my thanks, appreciation and gratitude to my honourable supervisor Dr. Can UZUN, who I was pleased to his supervision on this research for his efforts to create a scientific environment and to overcome all the difficulties that I faced throughout the research period. I extend my thanks to the Altınbaş University, Department of Architecture, for supporting me in completing this work. I special thanks to my father, who supported me with his prayers, and my kids, who was my support at this stage and did not leave me alone at all times with such circumstances. I appreciate my friends and everyone who encouraged me and contributed to the success of this study.

Finally, I would like to thank everyone who helped me with their advice and efforts.

ABSTRACT

CONTEMPORARY BUILDING TECHNICS USING CONVENTIONAL MATERIALS, OF CLAY AND MUD

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In this study, the extent of the possibility of using clay in contemporary architecture was addressed. To achieve the objectives of the research, the study was divided into three sections, which are the forms of using clay in contemporary architecture, the benefits of using clay in contemporary architecture, and the disadvantages of using clay in contemporary architecture.

The research methodology was based on collecting the literature in sections related to the topic. Then the Delphi method was applied by adopting two rounds to determine the most important factors for the use of clay in contemporary architecture. After that, in-depth interviews were conducted with three experts and the results of the literature, the results of the Delphi method, and the results related to the interviews were compared to reach the final results.

The study affirmed that clay can employed in contemporary architecture efficiently in different forms : integrating clay with 3d printing technique, rammed earth structures ,compressed blocks , terracotta panels and plasters solutions .Also, the study revealed that the most benefits of clay utilization in contemporary architecture are : durability of the building ,saves energy ,reduce co2 emission, save energy ,control heat indoor the building ,economic , achieves sustainability in addition to Aesthetic aspect .While the disadvantages

of clay utilization in contemporary architecture are : poor earthquake resistance , lack of bearing capacity to high loading ,lack of regulations and standards , lack of knowledge of mud architecture , lack of skilled labor in earth construction . The study recommended to conduct more researches to innovate clay utilization in contemporary architecture by investigate integrating clay with other materials help to enhance clay properties.

Keywords: Earth Construction, Clay–Contemporary Architecture, Delphi Technique.

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ABBREVIATIONS

ABC	:	Auroville Building Center
CMB	:	Compressed Mud Brick)
CF	:	Critical Factors
SEB	:	Stabilized Earth Blocks

1. INTRODUCTION

1.1 INTRODUCTION

With the development of materials and modern methods of construction, new methods have evolved to produce and develop alternative building materials, for example, clay, with modification and development in its properties to make it better than those that were created in the past. The incineration method is one of the oldest technologies. It is mixing and stabilizing clay with other cementing materials such as cement, lime and/or other waste materials. Mixing and stabilizing clay with other materials or secondary materials has many benefits such as reducing backfilling, solving waste management problems, protecting the environment and saving energy., which in turn reduces the cost of the final product (A. Seco et al. 2017).

In recent decades, most homes were built using traditional building materials such as clay, which is one of the most important local building materials available that achieves a degree of reliability for construction by reducing cost and ensuring a high degree of quality, in addition to being the only natural building material that is extracted from the soil in that period, it includes economic, social and environmental sustainability standards, as it is today considered exemplary actions to preserve the environment and take into account the economic and social aspects (Udoudoh, et al, 2021). Building materials are considered one of the most important priorities that contribute to achieving the sustainability of buildings, as sustainable building materials can be traditional, due to their abundant circulation in the construction industry in addition to being cost effective. With regard to modern and contemporary building materials, they are considered more advanced than traditional materials in terms of technology in terms of ease of use and speed of implementation in addition to being economically feasible, which makes them achieve effective sustainability for buildings in a way that contributes to achieving environmental well-being and finding modern alternatives to traditional building materials through the application of pillars The three main ones for sustainability which include (F. Lord, 2020):

a. Economic Sustainability
b. Social Sustainability

c. Environmental Sustainability

The vital role of modern and contemporary building materials is highlighted by the sustainability of building materials resources that contribute to achieving high quality requirements for facilities in the construction industry and achieving environmental standards using building techniques that consume limited amounts of energy (Stevulova et al, 2017).

The use of clay contributes to improving the engineering and environmental characteristics of the construction industry, by covering landfill areas and building material waste, and lining water bodies such as lakes, ponds, and water channels, where the clay material is subjected to additional processing of the grinding and sifting stages to get rid of the solid particles and the contaminated materials suspended in it (Derby City Council, 2021).

Traditional building materials are of an important nature in the construction industry in general and for the architectural formation in particular, as they began to develop gradually and significantly with the development of building materials and methods of their implementation in construction projects, which contributed to the creation of architectural appearances of an aesthetic nature for buildings (Mostafa et al, 2022).

Building materials as clay, using contemporary building techniques, contribute to achieving a balance for the structural elements by improving construction performance, ensuring a high degree of quality, the ability to form easily, and maintaining the flexibility of materials for the internal and external facades. Moreover, it clearly affects the architectural design of buildings to show the building's structural systems in an aesthetic way and has a unique architectural structure, in light of the great development in traditional building materials and the development of knowledge of its structural and architectural characteristics (Qassem et al, 2017).

Figure 1.1: Clay and its Combination with Other Materials in Construction.

1.2 PROBLEM STATEMENT

The study problem is summarized in not using traditional building materials in the projects that are nowadays being executed in the several project phases. A number of technologies are used to carry out the project work, including contemporary building materials. Therefore, traditional materials such as clay are sought after.

If there is no solution for this problem, it results in a number of problems related to the building's temperature and internal humidity, and this will lead to a number of accumulated problems in the field of architecture that limit making the construction buildings perfect and sustainable, which sometimes leads to the stopping of the entire project as a result of not using traditional building materials such as clay.

Traditional building materials are used to implement the project works more accurately and compare them with the current contemporary methods to know the level of accuracy in the implementation of the works and thus reduce the waste of resources.

Also, there is still a weakness in knowledge of the forms of using clay in contemporary architecture as a building material and the methods of its construction. There is also no sufficient evidence or academic studies encouraging the use of clay in contemporary architecture, in addition to the lack of comprehensive evidence showing the benefits and disadvantages of using clay as a building material in contemporary architecture. Therefore, This study attempts to fill these research gaps by exploring the forms of using clay, the

benefits of using it, and the disadvantages of using it in contemporary architecture and providing a comprehensive guide that benefits the construction industry to adopt its use in contemporary architecture. Consequently, this study answers the main question :

a. what are the clay Contributions as building material in contemporary architecture?

And these questions can be derived from the main question:

a. What are the forms of clay utilization as building material in contemporary Architecture?
b. What are the benefits of using clay building material in contemporary architecture
c. What are the disadvantages of using clay building material in contemporary architecture

1.3 AIM OF THE RESEARCH

The aim of the research is to find out the impact of materials on clay material project's construction work in order to generalize it and encourage the construction industry to employ it and minimize the resources waste, specifically after the technological development and the using of technical methods in the implementation of construction works with an extremely elevated precisely compared to contemporary techniques.

Due to the spread utilize of contemporary construction techniques using traditional materials in projects, engineers and experts do all their best to develop and enhance performance in projects, that simplify the process of project management.

Research objectives include:

a. Executing extensive reviews to assess the clay utilization in contemporary construction projects.
b. Investigate the impact of using clay in contemporary construction by examining its advantages and disadvantages on contemporary building architecture
c. Provide guidelines can add beneficial contribution to the architectural designers, construction industry, academics about the benefits of clay in contemporary architecture.

d. To shed light in benefits of clay material to achieve sustainability in contemporary buildings

1.4 WHY CONTEMPORARY BUILDING TECHNIQUES?

Architecture is a guide to the development of countries, and through it the culture of society is understood through the visual phenomenon of buildings that are in the most beautiful aesthetic and architectural form, as this depends on the taste and sense of the architect who always seeks to highlight the aesthetic architectural aspect of buildings through the use of the latest contemporary and modern construction techniques which saves a lot of time and effort in addition to raising the quality of construction (Tobolchik, 2021).

We take advantage of modern building methods in developing new building styles to obtain a contemporary life effect that serves the culture of society in terms of architectural design and concept, as it helps to get rid of traditional building designs and maintains building developments continuously with modern technology. developments, to distinguish unique buildings with an ideal creative palette to make life better, making it easier for the architectural designer to use designs with modern technologies that meet the needs and requirements of the owner by following innovative and future methods. The set of materials and composition of the basic version of Building Materials has changed for Building Materials. Ancient Over the past ages, humans have used some elements to build buildings, such as clay, mud bamboo, wood, and rocks. Buildings and art materials are becoming more modern,) Dye. Saeed Ahmad. Muhammed.

Traditional building techniques improve the quality of the internal environment of buildings due to its vital role in taking into account the health of the residents of those buildings, in addition to providing thermal comfort and indoor air quality directly, so care must be taken to provide an appropriate environment that is compatible with the internal environmental quality standards to achieve a balanced system that is compatible with the conditions Environmental and climatic to make the interior spaces comfortable and not to cause negative impacts on the green building system (Alama, 2020).

Buildings must have an effective and high-quality indoor environment system to ensure that building moisture is reduced, which contributes to making construction of effective quality and maintaining the durability and strength of green buildings. (Radwan, 2014).

Traditional construction is one of the normal construction methods in which traditional buildings rely on old building methods consisting of old building materials such as bricks, cement and mud, which are assembled and manufactured on site to be used for construction purposes (Fierascu et al, 2019).

Clay is considered one of the most prominent building materials that were used in the past in the construction industry, as it is fine granules extracted from natural rocks or formed from clay soil material. It contributes to increasing the strength of the building mixture, providing thermal insulation for buildings, and making them sustainable, in compliance with green building standards, by making them more comfortable (Muntari and Windapo, 2020).

Figure 1.2: The Influence of Modern and Traditional Building Materials.

Figure 1.3: Preserving Nature and Designing Sustainable Buildings.

To understand the impact of utilizing clay in contemporary buildings, this study followed 4 steps:

a. Step 1: Formulation of study objectives and methodological framework in light of the literature review): This stage required an extensive review of literature on the benefits and disadvantages of clay in contemporary construction.

b. Step 2: this step depends on exploratory stage using the Delphi technique: This stage utilized the Delphi technique where an experts responded to questionnaires in two rounds to attain a consensus to the benefits and disadvantages of utilizing clay in contemporary architecture.

c. Step 3: This step utilized a number of in-depth interviews with the aim of determining and verifying the benefits of clay as building material in contemporary buildings. This verification stage played a significant role in determining distinctive, valuable advantages and hidden agendas (such as the situation upon which the clay construction is useful are not well interpret).

d. Step 4: The aim the final stage was to synthesize the study results; summarize and discuss the knowledge contribution of the findings make to academia and the construction industry.

2. CLAY CONTRIBUTIONS IN CONTEMPORARY ARCHITECTURE-LITERATURE

Clay is considered a traditional and contemporary building material spread in various countries of the world with various technologies, as it conforms to the standards of building systems mixed with beauty and its ability to reduce the internal heat of the building, and contributes to making the building economical, which makes architecture based on clay more comfortable and able to improve indoor air quality and reduce humidity (Danal and Sharma, 2017).

The impact of modern materials and building techniques on architecture appeared in a very general and aesthetic way, and on the architectural formation in particular. A building systems have developed significantly in recent times through building materials, construction systems and implementation methods New materials and modern and diverse construction techniques have emerged that gave freedom of creativity and gave a new thought to construction ,The different unique construction and formation, as well as the new architectural formations, hence the research problem in Ignoring the role of modern building materials and techniques on the architectural formation , The research had to be justified in the light of following information, what is the concept of modern technology, its development and its link with the concept of architectural formation, the influencing elements, and the relationship of modern and traditional materials in architectural formation Modern The research is interested in shedding light on the impact of modern building materials and techniques that they play with its techniques on architectural formation (Mustafa. Hape, 2022).

Compounding a material for molding a new material Building a new material in the construction of a new material A new material in the construction of other materials, consisting of voids as a result of the shape of the grains or particles, so the grains of gravel or sand are other circular or in other shapes, which leads to a number of voids, and the more voids the more Decreased soil cohesion. What happens in practice is that if the soil is not cohesive, then the size of the granules is determined and mixed with smaller granules, so that they fill the voids between them. It occurs in the case of walls built with compressed mud. What happens in practice is that if the soil is not cohesive, then the size of the granules

is determined and mixed with smaller granules, so that they fill the voids between them. (Aba Al-Khalil. Ibrahim, 2017).

Clay architecture is a type of traditional architecture based on the building material (clay), which is formed from raw soil without the need to ripen it on fire and without any chemical additions, rather, all its components are considered natural materials such as gravel and dirt, where it is and water is added to form a dough and from it is formed the soft clay is placed in molds and dried under direct sunlight, and sometimes it is roasted in special ovens for that, to be ready for architectural construction operations, especially in building and cladding the stone walls of buildings (Gömze et al, 2019).

Figure 2.1: Clay Uses in Construction.

Figure 2.2: Methods of Making Clay Molds.

The developed countries witnessed a development in the techniques of building materials in the field of architecture, and some of them dispensed with building with clay and resorted to the use of new building materials in advanced buildings, which need huge financial and natural resources, in contrast to the building material made of clay, which is compatible with the natural climatic conditions of the advanced buildings and in turn works on improving the indoor air quality of buildings and reducing humidity (Kumari and Mohan, 2021).

Figure 2.3: Design of Traditional Buildings by Using Clay Material.

Figure 2.4: The Use of Architectural Formation of Materials with Clay.

2.1 CLAY PROPERTIES AND COMPOSITION

The study of the technical properties of traditional building materials (clay), especially the physical and chemical properties, is an important factor in the building industry and architectural formation, and the knowledge of the mineral composition and its impact on contemporary building techniques. Clay consists of crystalline materials with certain properties consisting of thin sheets of silicon, aluminum, hydrogen, oxygen and other elements that contribute to the formation of the crystalline form of clay (El Halim et al, 2018).

Figure 2.5: Reinforcing the Walls with Mud.

Architectural projects consume large amounts of resources and produce quantities of waste, as contemporary building materials cause large emissions of energy that reduce the sustainability of architectural buildings, so it is necessary to use clay in the manufacture of architectural buildings for its vital role in achieving the sustainability of green building and preserving interior buildings from Humidity and other architectural problems, especially since sustainable architecture is based on several principles centered on preserving the health and comfort of the occupants of those buildings, achieving sustainability standards in buildings over their life span within the stages of construction, operation and future maintenance (Narendhran PS et al, 2023).

Among the most important characteristics of clay construction are the following:

Figure 2.6: Characteristics of Clay Construction.

Clay has the property of absorbing moisture inside architectural buildings, as this property contributes to preserving the health of the occupants of those buildings and providing a healthy climate throughout the building's construction period, in addition to the ability of clay to store quantities of heat emitted from the sun's rays and keep them inside the building (Gramlich, 2013).

(Bernardo-Arugay et al, 2023) explained that clay does not consume a high amount of energy during its formation and manufacturing process, in addition to saving transportation costs, unlike contemporary building materials that need modern, contemporary equipment during manufacturing and operation processes in advanced factories.

In turn, (Rybak-Niedziółka, 2022) indicated that clay as a traditional basic building material can be recycled and used in architectural construction work at any time, unlike modern building materials that are difficult to get rid of, which in turn destroy the environment and

reduce the sustainability of contemporary buildings during maintenance and demolition operations.

Clay is one of the traditional building materials that is easy to form and use in architectural construction works, due to its ease of learning without the need for modern and contemporary equipment, in addition to the ease of the preparation and construction process using a small number of building materials equipment, which in turn makes it easier for the owner to choose the best way to build within the appropriate architectural framework of the building (S Lima et al, 2017).

Figure 2.7: Maintaining the Basic Shape of the Clay Unchanged.

Clay is considered the oldest traditional building material used in the construction of contemporary buildings, due to its great ability to harden and form under specific conditions. It is easy to use for a variety of purposes in the construction of contemporary architectural buildings, where (Almssad et al, 2022) pointed out that clay enters the construction of architecture as it is the principality of clay for various developed countries as it is a basic material for many natural building techniques and its use in various construction purposes such as floors, paint and architectural decoration processes.

2.2 CLAY USES IN THE CONSTRUCTION INDUSTRY

Evolution and change have been observed in the industrial fields that work in improving and shaping architectural buildings and maintaining their sustainability well. it can conflict with environmental or human factors. therefore, we must preserve the materials that benefit the environment and do not cause pollution in the environment. (El-Adl. Asma, 2022).

Figure 2.8: Components of Sustainability.

Clay is used in the construction of buildings as a natural organic material so that it can be recycled and used in cement-concrete mixtures, as it can largely replace contemporary construction techniques in the construction industry in most countries of the world. (Maeijer et al, 2021) pointed out many of the physical and chemical properties of clay that contribute to enhancing, improve the properties of the cement mixture, and raise the quality of construction, in addition to preventing the occurrence of moisture inside the buildings.

The use of traditional building materials in the construction industry, such as clay, led to the development of the construction industry by improving the quality of contemporary building techniques and raising the management of architectural projects, as it plays a basic function in the field of architectural formation in relation to the field of implementation and operation, in addition to the high ability to reduce the amounts of waste generated on construction sites, through the implementation phase and ending with the delivery phase during the project life cycle (Lekan et al, 2022).

Figure 2.9: Forming by Clay and Its Uses in Contemporary Construction.

Khubaev et al. (2018) stated that in the contemporary construction of architectural buildings, there is always an urgent need to improve the external and internal appearance of the building, in addition to developing the durability of the building through the use of contemporary traditional building materials (clay), which contribute to maintaining the reliability and economical construction by resisting the external influences surrounding the buildings with a stable degree building heat and achieving internal balance.

In the same view, (Javadi et al, 2015) mentioned that the traditional building materials have the permeability feature by reducing the water absorption rate during the cement mixtures, which helps in controlling the moisture rate inside the architectural buildings in order to ensure obtaining sustainable contemporary buildings. The researcher concluded that all of this contributes to providing comfort and improving the lives of the residents of those buildings as a result of the application of contemporary traditional technology in the construction industry by providing the necessary equipment and conditions for mud architecture.

Figure 2.10: Transforming Clay Into an Easy-to-Form Construction Material.

Many developing and developed countries resort to the use of traditional building materials and encourage their application in the construction industry because of their unique urban style that contributes to preserving the beauty of the sites surrounding those buildings and providing green space within the framework of sustainable development of green buildings, which leads to the preservation of cultural and urban heritage by restoring buildings using traditional materials (clay) while dispensing with contemporary construction techniques (Rybak-Niedziółka et al, 2022).

Figure 2.11: The Combination of Traditional Materials and Modern Architecture.

2.3 FORM OF USING CLAY IN CONTEMPORARY ARCHITECTURE

2.3.1 Compressed Clay Blocks

Novel technologies have modernized clay materials utilization in order to upgrade its workability. Automated compressed earth blocks consist of integration of dried clay and sand and manufacture utilizing a mechanized hydraulically compressed block machine with several blocks patterns as illustrated in Figure 2.12.

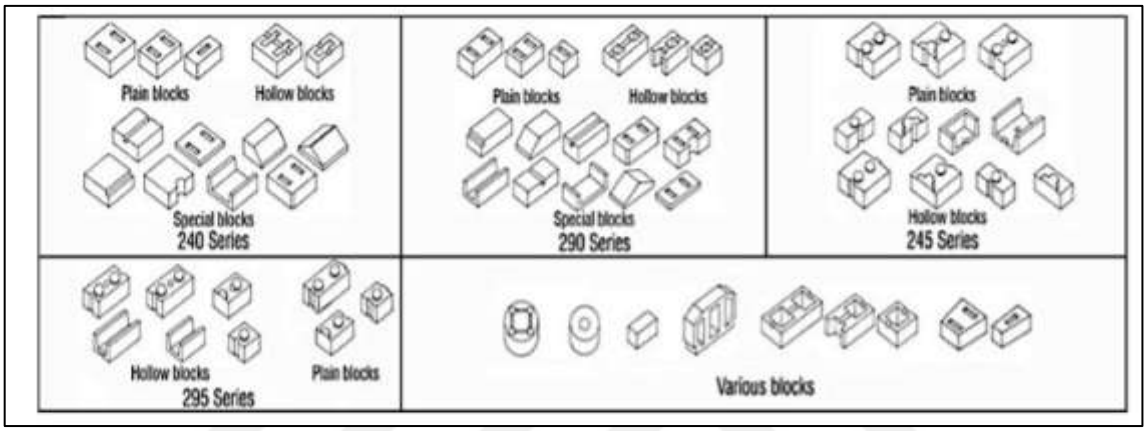

Figure 2.12: Compressed Clay Blocks.

One of the remarkable enhancements noted in these blocks is its bearing capacity which is equals to two-third that of blocks manufactured from concrete (Muazu ,2017). Moreover, Clay bricks are inexpensive than fired bricks and blocks manufactured from concrete. compressed stabilized earth bricks can be enhanced using other technique by using low cement fractures during the production process. The block comprehensive resistance, water resistance is better than the clay block without adding cement. The energy demands of stabilized compressed raw clay blocks is 3-5 times least than the traditional fired bricks (Auroville, 2009).

2.3.2 Rammed Earth

The rammed clay blocks are manufactured on the ground, in a mould with various dimensions. The earth is prepared in successive strata as depicted in Figure 2.13

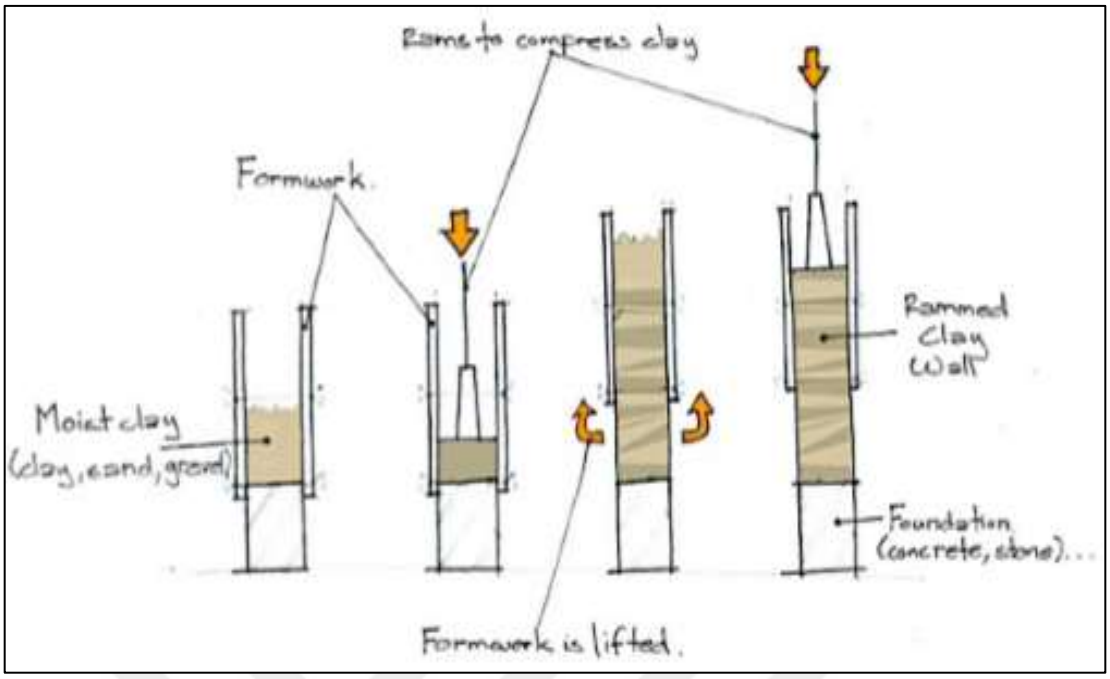

Figure 2.13: Construction Method of Rammed Earth Wall (Leo Espinosa, 2017).

Building a clay house characterized several environmental advantages in addition to low costs Moreover, a clay house can appear extremely modern. It can mention a project conducted by a Chinese design firm Hypersity as illustrated in Figure 2.14. Their designers were inspired by the traditional houses and invented nice house with bent walls. The house consists of rammed clay walls, the firm utilized rammed earth method to construct this house, and this house is a magnificent instance of how conventional methods still have a significant role in the advanced world, particular one where upgrading sustainable living is extremely significant.

Figure 2.14: Clay House in by Hypersity Firm (Yang Shi ,2016).

Djamil (2016) explained that the rammed earth requires the mold construction within which the clay is compressed. Such molds, that should be robust enough to bear the compression pressure of are conventionally formed using piles sections collected together and executed to slide along the wall after it is compressed about 10% of its entire weight comprise of water. Figure 2.15 illustrates a rammed clay house instance.

Figure 2.15: Rammed Earth Home Djamil (2016).

2.3.3 The 3D Printing Robots

3D printing considers one of the novel improvements in construction industry and architecture is 3D Printing with the use of different material. 3D printing considers of the novel improvements in construction and architecture with the utilization of several material. This method can development the chance for personalization of residential housing with large scale. Recently, 3D printing considers of the fastest developing technologies all over the world. The 3D printing technology was motivated by the construction sector's requirements for fast and cost-efficient prototyping production technique (Nadarajah, 2018). It minimizes costs afford on the project by reducing waste and overproduction in addition to reducing the labor utilization (Malaeb et al, 2015). The 3D Printing field has a magnificent future in the architecture field and detecting the significant parameters of 3D printing technique in the contemporary vernacular architecture design depend on natural substances like clay. The FabClay project example is the project that illustrates the novel insight of architectural design and constructions. This project is a 3D printing project seeking to detect a novel digital manufacture system. It is a robotic additive manufacturing processes using industrial a robot and new 3D printing technology. It has begun with conventional techniques of building with natural substances and going on extending the links

between architecture and novel technology. The second projects is 'Gaia' project which is an architectural housing project and can be considered as the first projects implemented by 3D printing robot that was considered a new architectural pattern contributes for sustainability to the environment. with considering to the natural materials utilization as shown in figure 2.16.

Figure 2.16: 3D- Printing Technique in Gaia Project (WASP, 2018).

2.3.4 Wattle and Daub

It is a plaster-based earth gained by blending fine soils, fibrous substances (such as straw, mud, clay, animal manure or sand) and lime. It closes any distances between the sections of wood wall. Figure 2.17 illustrates a timber-framed structure utilizing the wattle and daub method.

Figure 2.17: Using Clay Infill with Timber-Framed Structure (Partridge et al, 2016).

2.3.5 Adobe

It is a very old-fashioned method of earth blocks construction manufactured from a mix of earth full of clay and a adequate quantity of sand to permit sufficient compressive resistance and minimize cracking. The fluid blend is to be cast into formworks to shape the bricks in the favorable size. The blend is allowed to cure until it is possible to eliminate it to let it fully dry in the sun. Figure 2.18 illustrates a village executed completely of adobe by Hassan Fathy (Djamil, 2016).

Figure 2.18: Gourna Village is Placed in Egypt.

2.3.6 Cob

This regime utilizes a mixture of clay, sand, straw and water to develop rigid bricks shaped loaf of bread that are located in the wall and then "woven" together to develop a uniformed block masses permit the formation of bent forms due to their malleability, but demand a lot of straw as illustrated in figure 2.19

Figure 2.19: Indoor of Cob Home.

2.3.7 Decoration

(Srivastava and Reddy, 2020) stated that a re-incorporation of the linkage between clay craft and architecture would introduce a sustainable solution to the contemporary buildings. The artists can execute the crafted clay wall models from their craft villages and transport them to the required locations. Combining several clay crafts with interior design would highlight in clay crafts and introduce a several insights on how the conventional clay techniques can be utilized in the contemporary day. Each wall can be as art work and clay walls are one of the inexpensive, sustainable and durable structures selections of construction. clay walls have been almost for more than 1,000 years and showed high strength during years while emitting their beauty and robust via periods. The wall can be classified into smaller blocks able to interlock to facilitate it to form with at the craft villages. Later, the Crafted wall bricks are interlocked and ordered on site. This can reduce the total cost and project period. consequently, preserving the culture and art of clay crafts.

Each wall regimes specified below are completely manufactured of Mud, stabilized with lime and natural additives. Following are the natural structure methods: Rock and cob, Wattle and Dub, Rammed Earth, Adobe, Earth Bag, CMB (Compressed Mud Brick), Mud 3D Printing, Cordwood Masonry

As for Rammed Earth Wall Art, the idea is to integrate the sand art method and earth ramming method to execute artistic walls in the inside the building.

Figure 2.20: Integration of art with Rammed Earth Wall.

While Cordwood walls with terracotta artifacts, this design presents substituting panels fabricated from wood with terracotta panels, Clay art bricks, and sculptures describe the place story.

Figure 2.21: Cob Wall.

Also, decoration using clay can be presented using Baked terracotta panels on earthen walls in which Baked clay panels have been utilized in several Indian shrines and temples. The panels utilized to illustrate the way of life and customs of the place. The idea is to introduce the clay panels with support pins and integrate them with rammed earth walls and cob walls

Figure 2.22: Terracotta Panels.

Earthen blocks for 3D walls, Hollow earthen Sun-dried Bricks can be made utilizing specified modes and ordered and sticked to for a 3D wall

2.3.8 Stabilized Earth Blocks (SEB):

In recent years, SEBs has attracted numerous architects searching on sustainable structure technologies, who reinvented the earth technique as a modern material in contemporary architecture. Nevertheless, the technique that has become common in the modern practice of innovative buildings is the production of (SEBs) —unbaked earth blocks of size 8″ × 6″ × 10″.SEBs are an innovative update of the brick encouraged by the Auroville Building Center (ABC) in India (Maini 1999). on the contrary of usual adobe block, that is a consists of mixing soil and water constituted in a wooden mould, the stabilized compressed earth block

has an conventional cement constitution in its mixture but a lower amount of water. The mix is not blend to access a plastic condition, but it mixed until the cement and soil are completely incorporated. After that, the mixture is located within a formwork and compacted with a high degree of pressure applied using a manual machine. The brick formation is as a result of the soil and cement compression in a humidity state (Dayaratne, 2010). Dried in the shaded sun, the SEB attains an elevated compressive resistance suitable in general for two storeys building but higher strengths can also be fulfill for 3- or 4-storey buildings (Maini 1999). The clay integration of other novel techniques enable developing possible earth structures that do not demand domes, vaults, and other shapes of this type , that utilized to be correlated with earth constructed structures (Fathy 1969). Clay blocks are left without plastering and often covered with plastered or are coated with watered earth, added with natural painting colors. Actually, the indoor temperature of an earth structure is approximately always lower than that of a similar traditional brick structure (Dayaratne, 2010).

2.3.9 The Contemporary Brick Methods

Nowadays, numerous examples utilized modern technology in building design and construction. Several architects and designers initiatived to re-assess garnished brickwork. Brick considers a credible material, but architects, builders, and sellers based on the brick wall aesthetics via investigating smooth and corrugated surfaces, several colors, and decorative inclusions.

Several brick structures all over the world have a magic not easily existed in timber or reinforced concrete structures. Brick architecture is superior of the of wooden architecture as a result of to the its fire resistance in addition to the advantages of developing a stylish look by integrating curved lines (arches). Concrete construction is also resistant to fire, like clay architecture, but clay architecture is superior to concrete construction from an aesthetic standpoint, as the building can be constructed in a variety of styles and with complex designs that cannot be found in concrete construction.

Bricks have superior corrosion resistance, and their great strength is owing to their strength to the negative influences of temperature and moisture. Bricks are also highly resistant to rot, unlike wood, which is resistant to fungi and deformations. Facing (facing, facade, finishing) brick has a high surface quality and an accurate, regular shapes. Additionally,

there are several selections for brick processing facades (smooth, wavy, rough, “antique”, etc.). Mortar strata in brick architecture is executed on ordinary and colored masonry mortars. Facade bricks permit to execute a creative architectural appearance, harmoniously integrated with the ceiling colour, windows, landscape and the ecology. Industries produce many kinds of facades bricks, as illustrated in Figure 2.23

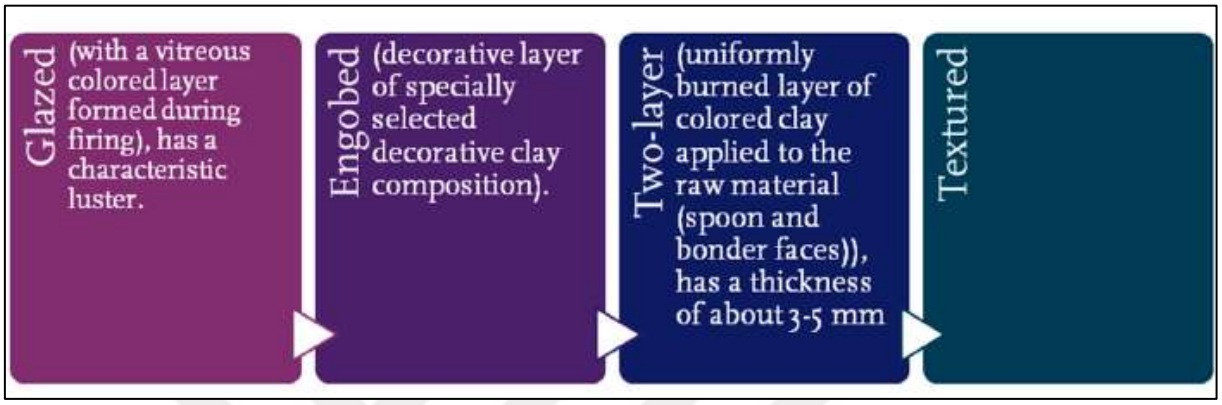

Figure 2.23: Types of Brick Surfaces.

Firebricks consider perfect if the project seeks to construct a wall, framework, or structure that is significantly resist fire. These bricks, also indicates to as thermal bricks, are manufactured from fireclay, a valuable clay that significantly includes silica and alumina. Physical characteristics of clay brick are elevated compressive resistance and low tensile resistance. Consequently, they are physical characteristics of clay brick are elevated compressive resistance and low tensile resistance. Consequently, they are inconvenient for tensile and bending elements, thereby preventing their extended utilization in several structural systems. For tensile and bending elements, thereby preventing their extended utilization in several structural systems.

Recently, there has been motivating orientation toward enhancing the outdoor appearance of buildings. So, face bricks with numerous sizes, shapes, colors, and textures have appeared.

Consider a building consists of bricks as illustrated in Figure 2.24 that illustrate red and rustic bricks are once again used in contemporary construction. the buildings in Figure 2.24 manifest to be ‘gentle giants’ or ‘ancient wise rulers’ in the contemporary cityscape, in opposite of the shines glass structures. All the proposals showed utilize brick to gain them a contemporary look while preserving classic aesthetic of the building (Letelier et al, 2022).

Figure 2.24: Clay Brick Utilization as a Major Material in Contemporary Architecture.

Facing brick walls are repeatly utilized as being significantly favorable to apartments, restaurants, and shops, and brick outdoor facades can attain a structure or house a cozier, more inviting feel.

Color is Major to how wall bricks appear and can enhance a building's visual appearance. Nevertheless, variations in Three components identify the color. As for the clay. According to research conducted by Sedat et al the clay bricks reddening was the major reason of the color variation that appeared after 975 ◦C. Consequently, the hue was the essential color factor in describing the variation in clay brick strength and it can be utilized as a quality index for strength of clay brick. The next in the arrangement of effecting color are the sand, engobes, and mineral pigments utilized to paint the surfaces of brick (Attalla et al, 2020; Muñoz et al, 2011). Baking bricks in an oven, result in changing in their chemical constitution, iron oxide is constituted, and the colour changes to red.

The third effecting factor is the temperature in the oven. A brick that contains higher iron higher enable the brick color to be pink; the differences in the burning temperature result in several shadows of red. Lastly, the result of forming yellow or white color in brick is owing to the huge amount of lime

Generally, as bricks are manufactured from open-air oven from burned clay, that includes iron oxidized to ferric oxide (high oxygen content, and dark red). However, in closed ovens with low oxygen, the burned bricks are blue.

since all the green brick ovens have ceilings and this kind of dome cannot be constructed as a major structure, the production of environmental bricks is greatly smaller than that of red bricks. Therefore, bricks that are greener than red bricks are manufactured; green bricks are more strength and then red bricks.

Figure 2.25: Various Bricks Textures and Colors in Modern Architecture.

2.4 BENEFITS OF USING CLAY IN CONTEMPORARY ARCHITECTURE

The construction industry in the field of architecture relies on clay as a main building material because of its characteristics and positives that make it capable of achieving sustainability for contemporary buildings, as it is considered a natural material in the hands of all countries of the world, it does not need skilled labor (ease of manufacturing) as is the case in contemporary building techniques, moreover, it contributes to achieving balance inside and outside architectural buildings (A Ángel et al, 2019). Clay minerals are classified according to the type of silicate plate that they consist of, as they were divided into two basic types:

a. The first type: kaolin group, which contains (kaolinite and halloysite)

b. The second type: which contains illite, chlorite, and montmorillonite (smectite) groups.

Semlali, 2018 referred to the advantages of using clay in the building industry as a good heat insulator and fire-resistant. These advantages help make contemporary architectural buildings warm in the winter and cool in the summer, compared to contemporary building techniques. In addition, the clay material contributes to the absorption of moisture generated inside the walls of buildings, which makes it able to withstand the surrounding conditions.

The chemical composition of clay is one of the most constrains facing the architectural field, because it requires greater control over construction and architectural formation processes, thus increasing costs related to reuse. Mostly the chemical composition of clay consists of alumina elements, iron oxide, quartz, calcium oxide, and other elements that include certain mineral compositions that achieve balance in cement mixtures in the construction industry (Bin Salieh, 2012).

The most important advantages of building with mud in the construction industry can be highlighted as follows: (Brito et al, 2023).

a. Ease of use of clay in the construction industry.
b. Clay is always available (basic building material).
c. Diversity in the ways of shaping the architectural structure.
d. Maintaining the internal balance of buildings.
e. Reducing humidity and maintaining constant temperatures.
f. Engineering properties of clay.

Figure 2.26: Building Design with Clay.

Figure 2.27: Architectural Formation of Clay in Construction.

2.4.1 Sustainability Benefits

Tale 2.1 presents review of Sustainability advantages of clay in contemporary architecture in which these reviews showed the importance of clay material to achieve sustainability in contemporary buildings

Table 2.1: Overview of Sustainability Benefits.

No.	Sustainability benefits	Authors
1	Clay material considers environmentally sustainable.	(Zami, 2020); (Sruthi, 2013); (Benyoucef, 2020); (Djamil, 2016); (Semlali, 2018)
2	Clay material saves organic materials, as wood.	(Zami, 2020); (Sruthi, 2013); (Benyoucef, 2020);
3	Clay walls absorb pollutants.	(Zami, 2020);
4	A natural material that is widely available	(Zami, 2020); (Sruthi, 2013); (Benyoucef, 2020); (Djamil, 2016); (Oumar et al, 2022)
5	It greatly controls humidity and heat	(Zami, 2020); (Sruthi, 2013); (Benyoucef, 2020); (Djamil, B. 2016).
6	Clay material can be recycled	(Zami, 2020); (Sruthi, 2013); (Benyoucef, 2020); (Dj; (Oumar et al, 2022) amil, B. (2016); (Semlali, 2018)

2.4.2 Economic Benefits

Tale 2.2 the beneficial contribution of using clay as construction material in contemporary architecture to in in which these reviews showed the importance of clay material to achieve sustainability in contemporary building in economic field.

Table 2.2: Overview of Economic Benefits.

No.	**Economic benefits**	**Authors**
1	Clay integration in contemporary architecture is economic.	(Zami, 2020); (Sruthi, 2013); (Djamil, B. (2016); (Semlali, 2018)
2	Clay architecture requires simple tools and equipment.	(Zami, 2020); (Benyoucef, 2020); (Djamil, B. 2016).
3	Using clay leads to for very robust and strong structures	(Zami, 2020); (Sruthi, 2013); (Benyoucef, 2020); (Djamil, B. (2016).
4	Clay considers energy saver material	(Zami, 2020); (Benyoucef, 2020); (Djamil, 2016).
5	Clay architecture offers opportunity for job creation.	(Zami, 2020); (Benyoucef, 2020); (Djamil, B. 2016).

2.4.3 Aesthetic Benefits

The world's attention is directed towards urban sustainability, as architecture is a vital and effective element in the construction industry through achieving development and the three basic elements of sustainability, which include (a) environmental, (b) economic, and (c) social sustainability, using clay in the construction of contemporary buildings (Abdulwaha, 2020). The visual aesthetic design of architectural buildings is very important to create a good space that gives an aesthetic architectural image, given that architecture is a unique bridge towards sustainable development, so architectural design throughout the ages and with technological development was a way to achieve sustainable development standards and sustainable green construction through the use of building techniques as effective as clay, which has a great role in architectural formation patterns (Abdulrasool et al, 2022).

Table 2.3 reviews aesthetic benefits of using clay in contemporary construction.

Table 2.3: Overview of Aesthetic Benefits.

No.	**Aesthetic benefits**	**Authors**
1	Clay architecture offers simple designs with high aesthetical value.	(Zami, 2020); (Benyoucef, 2020);
2	Clay architecture upgrades heritage, tradition and cultural practice.	(Zami, 2020); (Benyoucef, 2020);
3	The possibility of creating decorations and engravings that suit modern architecture	(Zami, 2020); (Benyoucef, 2020);
4	Clay is aesthetic and versatile material, with his various colors (white, red to coalblack)	(Zami, 2020); (Benyoucef, 2020);
5	Unlimited designs, shapes, and surfaces using clay material	(Zami, 2020); (Benyoucef, 2020);

2.4.4 Structural and Technical Benefits

The utilize of conventional building materials like clay in the construction of contemporary buildings helps to improve the level of the construction industry, which leads to the development and modernization of the contracting company's system through the application of effective techniques that contribute to achieving the sustainability of construction over the life span and achieving green sustainability standards in architectural buildings (Gontar et al, 2019). Singh, 2022 mentioned that the traditional clay used in the construction of contemporary buildings is in line with the thermal requirements of the building, which leads to achieving comfort for the residents of those buildings, as the clay architecture relies mainly on the clay material towards a vision of its sustainability because of its characteristics that distinguish it from contemporary construction techniques:

a. Free natural building material.

b. Ease of manufacturing and operation.

c. The competitive advantage of obtaining a fixed thermal system compared to contemporary building techniques.

d. The clay-brick building has a healthy climate for its residents.

e. Thermal storage capacity for interior architectural buildings.

(Oumar et al, 2022) indicated that the advantages of using clay in the construction industry exceed its disadvantages, especially when adhering to the correct standards specified for architectural construction, and they can be summarized as follows:

a. Clay is a strong building material that is resistant to environmental conditions such as disasters.

b. Clay construction is characterized by moderate temperatures (thermal insulation property).

c. The ability to recycle mud buildings (future restoration).

d. Clay's ability to decompose (the property of maintaining the indoor air quality of buildings).

e. The ability to adapt to climatic conditions unlike contemporary building techniques (the internal stability characteristic of architectural buildings).

Figure 2.28: Fusion Between the Past and the Present.

Table 2.4 presents Overview of Structural and Technical Benefits of using clay in contemporary architecture.

Table 2.4: Overview of Structural and Technical Benefits.

No.	**Structural and technical benefits**	**Authors**
1	Clay characterizes high-energy storage capacity	(Zami, 2020); (Sruthi, 2013); (Benyoucef, 2020); (Djamil, B. 2016).
2	Clay materials contribute to minimize the energy depletion of buildings	(Zami, 2020); (Sruthi, 2013); (Benyoucef, 2020); (Djamil, B. (2016); (Semlali, 2018)
3	Clay can significantly resist fire.	(Zami, 2020); (Benyoucef, 2020); (Djamil, 2016); (Semlali, 2018)
4	Clay buildings characterize durability.	(Zami, 2020); (Benyoucef, 2020); (Djamil, B. (2016).; (Oumar et al, 2022)
5	The clay wall is an excellent sound insulator	(Zami, 2020); (Djamil, 2016).; (Oumar et al, 2022)
6	Clay has low heat conductivity and characterize high efficient thermal insulation	(Zami, 2020); (Benyoucef, 2020); (Djamil, 2016); (Semlali, 2018); (Oumar et al, 2022)
7	Clay material results in resisting buildings.	(Zami, 2020); (Sruthi, 2013); (Benyoucef, 2020); (Djamil, 2016).

2.5 DISADVANTAGES OF USING CLAY IN CONTEMPORARY ARCHITECTURE

Despite the beneficial contributions of concrete for its use in contemporary construction, which were reviewed previously, there are some limitations to its use in modern architecture. Table 2.4 includes a review of the obstacles that limit the use of concrete in modern architecture.

Table 2.5: Barriers of Using Clay in Contemporary Architecture.

No.	**Disadvantages**	**Authors**
1	Clay architecture can't resist earthquakes	(Zami, 2020) ;(Jamal,2017)
2	Clay architecture less durable, structurally lower, and poor technically.	(Zami, 2020); (Jamal,2017)
3	Clay walls require high wall thickness.	(Zami, 2020);
4	Misunderstanding, lack of awareness, and lack of skill amongst professionals, governments and all stakeholders.	(Zami, 2020); (Djamil,2016).
5	Clay construction requires much time and labor	(Zami, 2020); (Jamal,2017)
6	Inadequate clay construction technologies	(Zami, 2020);
7	Lack of training and courses on clay construction	(Zami, 2020); (Djamil,2016).
8	Lack of interest by clients in the thermal comfort and aesthetic aspects provided by mud architecture	(Zami, 2020); (Djamil,2016).
9	Absence of building standards and regulations.	(Zami, 2020);
10	Clay material has low tensile strength	(Zami, 2020); (Djamil,2016)' (Jamal,2017)

3. METHODOLOGY ADOPTED IN INVESTIGATION STUDY OF CLAY UTILIZATION IN CONTEMPORARY ARCHITECTURE

This chapter discuss the study methodology adopted to collect and analysis data. The research methodology comprises four stages were explained and interpreted. Also, this chapter includes description of Delphi technique and in depth- interviews employed in this study. Moreover, this chapter introduces information of experts and professionals participated in questionnaire Delphi method and in-depth interviews. Also, this chapter introduces mechanism of synthesis the outcomes obtained in this study.

3.1 STAGES OF INVESTIGATING CLAY UTILIZATION IN CONTEMPORARY ARCHITECTURE

The literature review in chapter two detects a general absence of new structured study, execute to determine the beneficial uses of clay in contemporary architecture in addition this study detects the critical factors comprise benefits and disadvantages can be influencing the acceptance of clay as a beneficial traditional material in contemporary architecture. As mentioned, factors determined by several authors in literature tend to present insights alone, and consequently lack investigation via structured methodological procedures. Thus, the major goal of this study is to offer a methodological method that offers validity to the kind of factors that can be influencing the acceptance of clay as traditional material in contemporary architecture. To attain this goal, a methodological framework that comprise four stages illustrate in Figure 3.1 was conducted:

a. Stage One: formulation forms of clay utilization in contemporary architecture, benefits and disadvantages as mentioned in the literature

b. Stage Two: Exploratory stage using Delphi technique.

c. Stage Three: Validation stage using In-depth interview.

d. Stage Four: research operation Synthesis and findings.

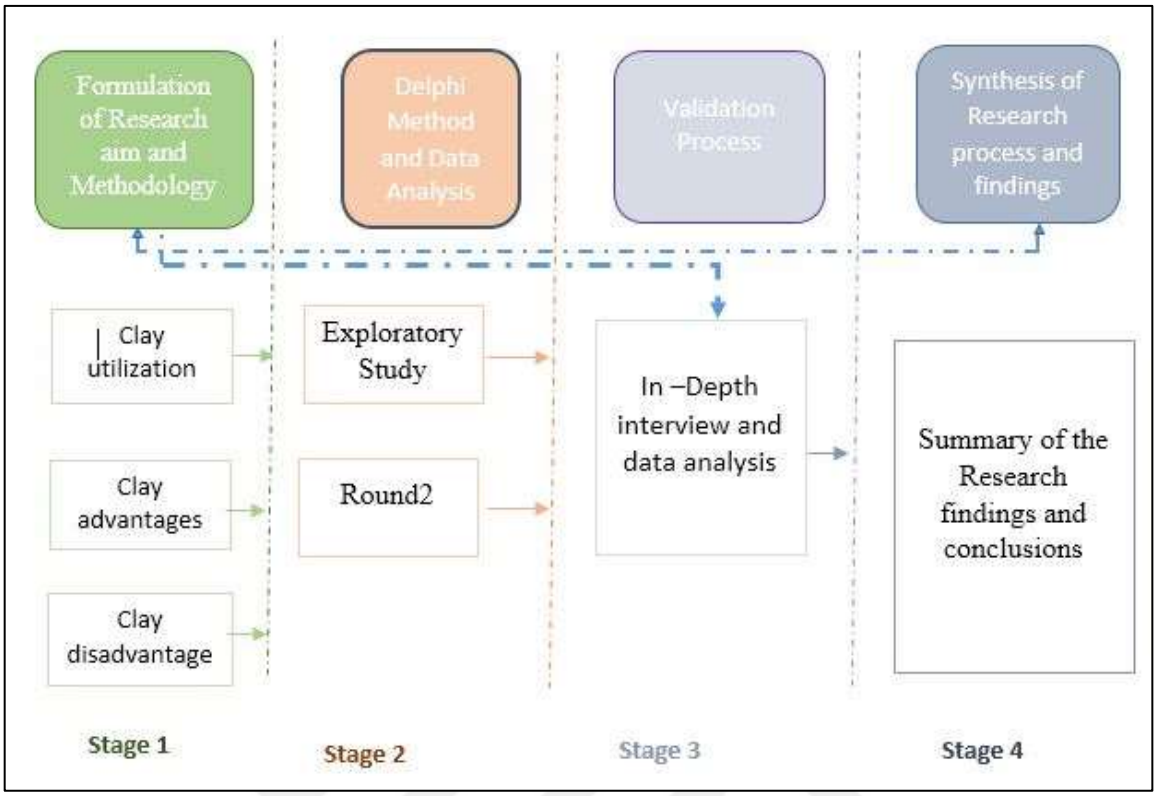

Figure 3.1: Research Framework.

To understand the advantages of utilizing clay material in the contemporary architecture, this study divided into four stages, methodological framework as illustrated in Figure 3.1. Stage One (Formulation forms of clay utilization in contemporary architecture, benefits and disadvantages as mentioned in the literature): This stage included a critical and extensive analysis of literature on the benefits of clay construction in the contemporary architecture. Comprehensive research on the literature revealed that the scientific verification, up t to date, on the topic of determination and understanding the advantages of clay as construction material, in specific in the contemporary architecture is very limited. After precise sight of the nature of the study rationale, an interpretivist philosophical method was employed to attain the purpose of the study. Stage Two (Exploratory study – the Delphi method): This stage used the Delphi technique where a professional team of participators replied to questionnaires in three rounds to attain a final decision to the benefits of utilizing clay material in contemporary architecture. In particular, this technique was selected as primary research method to consensus scientific data to strength the forms of clay utilization in contemporary architecture, clay advantages in contemporary architecture and clay disadvantages concluded from the literature review (as illustrated in Table 3.1, Table 3.2 and

Table 3.3). The data gathered from the Delphi method, integrated with the extensive literature review, resulted in an extensive list of forms of clay utilization, advantages and disadvantages in contemporary architecture correlated with clay construction and introduced data from which a strong interview schedule was structured for the validation stage (phase Three) such as in-depth interviews with experienced professionals have experience in earth construction. stage three (verification stage of in-depth interviews): This phase used a number of in-depth interviews in order to identify and validate the benefits of clay as building material in contemporary architecture. This verification stage played a significant role in determining distinctive, valuable advantages and hidden agendas (as the cases upon which the clay architecture is beneficial are not extensively interpreted) in particular within the context of the contemporary architecture. The consensus of this verified data permitted the researcher to execute a robust basis of understanding the diversified, known, and unknown and conditions of benefits and then enhancing the general advantages to understand them better in contemporary architecture. Stage Four (the research process Synthesis): The goal of the last stage was to consensus the study outcomes; summarize and discuss the contribution of knowledge the outcomes introduce to academia and the contemporary architecture; recommend future works and acknowledge restrictions. This final stage simplifies a comprehensive holistic understanding of the benefits of clay material in contemporary architecture. Taking into account the exploratory nature of this research, four phases- methodological framework was adopted. Each phase gathered major data that helped and contributed to the improvement of the subsequent phases.

3.2 RATIONALE AND OPERATION OF IMPLEMENTATION OF THE DELPHI TECHNIQUE

As illustrated, two Key techniques were utilized to gather data. In particular, the Delphi method and in-depth interviews were utilized owing to their ability to detect the forms of using clay, advantages and disadvantages in contemporary architecture. Delphi technique is utilized to solve a problem of getting information about any phenomena and that there is lack of knowledge about it (Adler and Ziglio, 1996), (Delbeq, et al,1975). Via this method information can be developed from the subjective views of professionals and experts on a collective foundation and this technique is convenient validating issues that are not suitable themselves accurate analytical methods (Adler and Ziglio, 1996). Thereby, Delphi method

contributed understanding the employment of clay material, detects fields about the benefits of clay building material that can have been neglected, fields where there are conflicting concepts and that do not have adequate guidelines to generalize. As mentioned, the literature review concluded that scattered studies produced proves validated through organized scientific operations with related to the advantages and disadvantages of clay construction. The Delphi method, consequently, was chosen as a primary study technique since it produced a more rigorous, informed and grounded way to detect the possible advantages of contemporary architecture. The Delphi method can get a more in-depth analysis of the advantages of clay construction from a carefully selected team of construction experts. The data introduces by the Delphi method introduced various knowledge assisted to knowledge in the field in relation to the kind of conditions that can require to be satisfied for clay employment in architecture.

The Delphi technique comprise two questionnaires' rounds, where the second questionnaire was structure from the questions and professionals' views concluded from the first questionnaire round. The purpose of the questionnaire in the first round was to extract forms of clay utilization in contemporary architecture in addition to advantage and disadvantages in order to compare the first-round findings with literature formulated in the similar regard. In the second round of the Delphi, the items determined from the first round were listed and ranked according to the number of professionals who determined each item. These outcomes (list of forms of clay utilization, advantages and disadvantages) were then returned to the professionals to give their second thought, reconsideration and conclude with final list. Of the little number of experts specialized on clay architecture all over the world, the most famous of this population were chosen as participators for the Delphi technique. Totally, 25 professional who were considered to have experience and knowledge regarded to the topic were selected. 15 professionals, a 60% response average, responded and approved to involve. Of the 15 participators, all of them were have practical experience but also acadimicians. The expert team needed only two rounds of questionnaire to access a consensus. Figure 3.2 demonstrate the methodological operation employed to implement the Delphi method in this study.

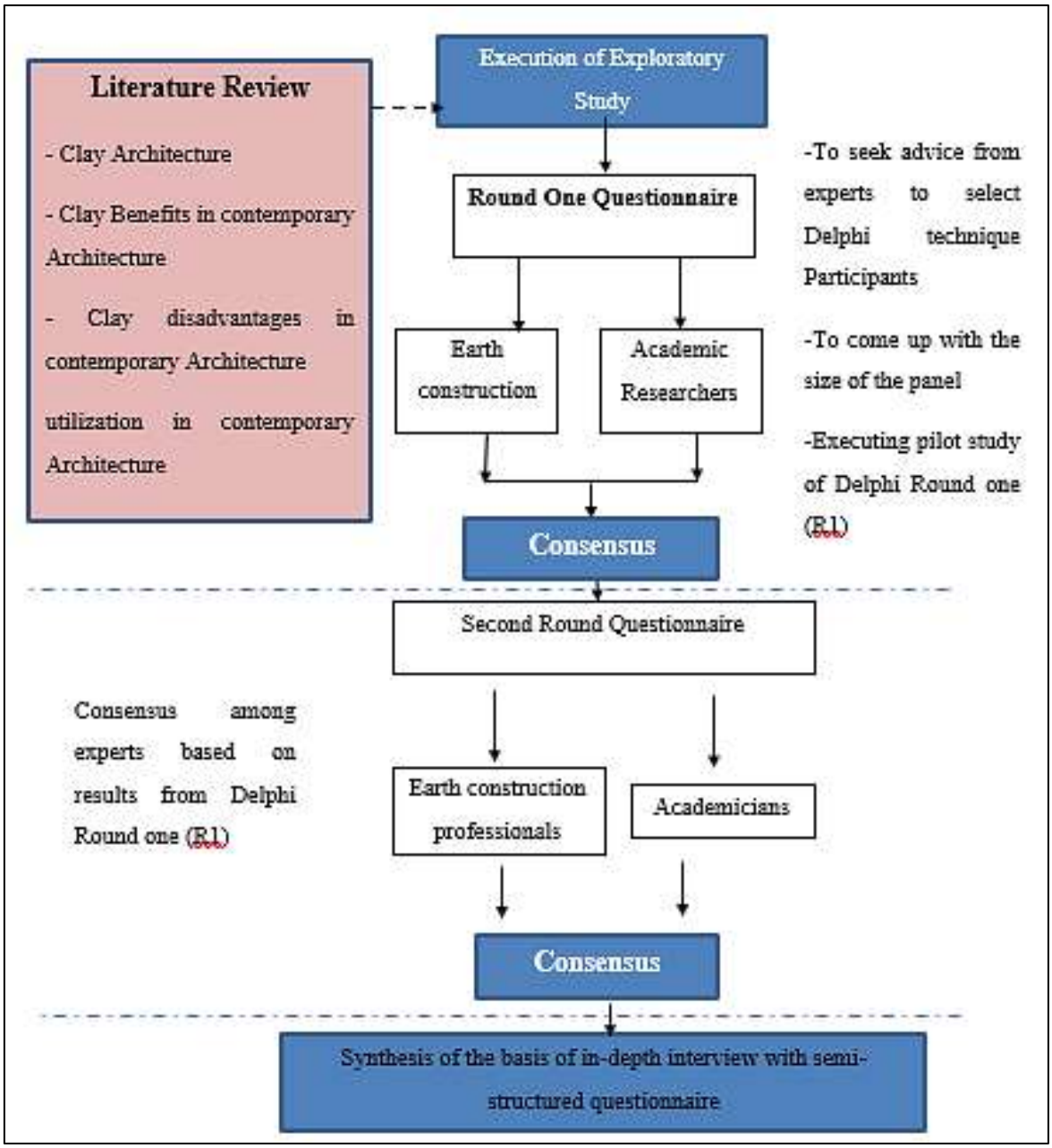

Figure 3.2: Delphi Technique Process Utilized in this Study.

3.3 RATIONALE AND OPERATION OF IMPLEMENTATION OF THE IN-DEPTH INTERVIEWS

The data provided using in-depth interviews earth construction experts were employed to verify the consolidated or generic list and develop a list of the form of clay utilization in contemporary construction in addition to advantages and dis advantages. In depth interviews are considered suitable qualitative technique to motivate participators to express their

personal feelings, views, and experiences (Mack et al. 2005). Interview technique assist to collect hidden information from critical subjects that stakeholders may be reluctant to discuss. The data gathered from the Delphi method integrated with the literature review in an extensive list and assisted directing the build of the interview schedule for the verification phase which is stage three. In specific, the third stage included in-depth interviews with professionals have a great experience in earth construction in the contemporary architecture. This stage played a significant role in shedding light on any features and hidden agendas. The data accumulation also permitted the researcher to construct a grounded basis of knowledge from which to detect the clay utilization in contemporary construction, its benefits and disadvantages.

Loosemore et al., (1999) stated that the researcher should ensure that the study methods utilized in any interviews should enable communicate most efficiently between researcher and the professional participator. Thereby, in a research, feedback is necessary convergence. It is the knowledge transited to the researcher from the participator. All the interviewees were an average of over thirty years experienced in earth construction. They achieved the following group of standards utilized to recruit participators with adequate experience in the area: trained construction experts with experience in clay construction who can highlight influencing beneficial contributions of clay construction in contemporary architecture.

In the third stage (interviewing), after establishing rapport, the experts were asked to discuss what they considered to be the employment of clay material in contemporary architecture, if any.

In this stage all the experts gave their own list of benefits; they were then illustrated the list of clay employment in the construction established from the outcomes of the Delphi stage and asked to verify by comparing between their own list. However, they were further asked to discuss and explain if there is any mismatch between the two lists. Each interview session lasted between half an hour to one hour. The interviews were recorded in audio and video tape to facilitate verbatim transcription.

The fourth stage involved transcribing where the author transcribed the audio and/or video in answer to each question. The transcripts were then analysed in the fifth stage (analyzing). This phase identified the meaning of the information gathered to achieve the goal of the

study and research whether more questions were required to illustrate any points regarded to the study aim. The sixth stage, validating, involved analyzing the reliability and validity of the data collected. Verification of the credibility and validity of the information was carried out by sending summarized final list of the benefits and all interview transcriptions together back to the all interviewees for their checking and final comments. The final phase comprised reporting the findings of the in-depth interviews in light of the entire study objectives.

4. RESULTS AND DISCUSSION OF CLAY CONTRIBUTIONS IN CONTEMPORARY ARCHITECTURE

Chapter 4 introduced all findings related to Delphi techniques and in –depth interview methods related to three parts: forms of clay utilization in contemporary architecture, benefits of clay utilization in contemporary architecture. This chapter provided findings of both of round one and two of Delphi techniques. In addition, this chapter compare the findings in depth interviews with Delphi technique findings.

4.1 DELPHI TECHNIQUE RESULTS (ROUND ONE)

The round one of Delphi technique included the experts in earth construction were asked the first round of the Delphi technique included asking questions through a questionnaire shown in Appendix A that includes three questions as follows:

a. What are the forms of uses of clay in modern clay architecture?

b. What are the most important benefits of using clay in modern clay architecture?

c. What are the disadvantages of using clay in modern clay architecture?

Experts and academicians provided their answers on relevant topics, and then the repeated answers were counted and arranged in the first round and compared with the literature in chapter Two.

4.1.1 Forms of Clay Utilization in Contemporary Architecture

The professionals were asked to determine the forms of using clay material in contemporary architecture and fifteen participators answered accordingly. Fifteen experts answered the section A of Delphi-questionnaire. The experts indicated to the forms of clay utilization in contemporary architecture. Each expert responded according to his knowledge of the forms of attribution of the uses of clay in mud architecture. After that, the experts' answers were collected by mentioning every use of clay in contemporary architecture, along with mentioning the number of experts who referred to each use. Table 4.1 presents forms of clay utilization in contemporary architecture according to round one of Delphi technique.

Table 4.1: Forms of Clay Utilization in Contemporary Architecture.

Round one of Delphi Technique	**Number of Experts**
Rammed Earth represented by rammed earth walls	12
Cob	3
Adobe bricks	5
Fired clay architecture	2
Plaster solutions	10
Compressed blocks	14
Integration 3D printing technique with clay architecture	14
Wattle and Daub	3
decoration using clay can be presented using Baked terracotta panels on earthen walls	9
Facade bricks	10

Referring to the literature in the second chapter, we note that all uses of clay in contemporary architecture that were mentioned according to the experience of the respondents in Table 4.1 have been reviewed in the literature. 14 out of 15 respondents indicated that the use of mud in mud architecture represents both of “Compressed blocks” and “Integration 3D printing technique with clay architecture” by percentage value 93%. 12 respondents hat presents 80% mentioned “rammed earth walls” as a form of clay utilization in contemporary architecture.” plaster solutions” and “Façade bricks “ achieved percentage value 67% where 10 experts recommended them .”Decoration using clay “ mentioned by 9 experts that achieved percentage value 60% .Only 5 experts mentioned “ adobe bricks “ as form utilization in contemporary architecture .Only three experts mentioned “Cob” and “ Wattle and Daub” as forms of clay usage in contemporary architecture. “Fired clay architecture” recommended

by two experts only which present the least form utilization of clay. Answers with few responses from experts and not relevant to the literature were excluded.

4.1.2 Benefits of Clay Utilization in Contemporary Architecture

The experts were asked to record the benefits of using clay material in contemporary architecture and fifteen participators answered accordingly. Fifteen experts answered the section B of Delphi-questionnaire. The experts indicated to the benefits of clay utilization in contemporary architecture. Each expert responded according to his knowledge of the forms of attribution of the uses of clay in mud architecture. After that, the experts' answers were collected by mentioning each benefit of using clay in contemporary architecture, along with mentioning the number of experts who referred to each benefit. Each expert mentioned at least five benefit of clay benefits in contemporary architecture. Table 4.2 presents benefits of clay utilization in contemporary architecture according to round one of Delphi method.

Table 4.2: Benefits of Clay Utilization in Contemporary Architecture.

Round one of Delphi Technique	Number of Experts
Clay material considers environmentally sustainable.	13
Clay material saves organic materials, as wood.	12
Clay walls absorb pollutants.	12
A natural material that is widely available	14
It greatly controls humidity and heat	14
Clay material can be recycled	13
Clay integration in contemporary architecture is economic.	13
Using clay leads to very robust and strong structures	5
Clay considers energy saver material	10
Clay architecture offers simple designs with high aesthetical value.	12
Clay architecture upgrades heritage, tradition and cultural practice.	9

Table 4.2: Benefits of Clay Utilization in Contemporary Architecture"Table Continued".

The possibility of creating decorations and engravings that suit modern architecture	11
Clay is aesthetic and versatile material, with his various colors (white, red to coalblack)	14
Unlimited designs, shapes, and surfaces using clay material	15
Clay characterize high-energy storage capacity	11
Clay can significantly resist fire.	12
Clay buildings characterize durability.	9
The clay wall is an excellent sound insulator	7
Clay has low heat conductivity and characterize high efficient thermal insulation	13

Table 4.2 shows that "Unlimited designs, shapes, and surfaces using clay material" was indicated by 15 experts while 14 out of 15 experts affirmed that the beneficial contribution of clay utilization in contemporary architecture are "A natural material that is widely available" and "It greatly controls humidity and heat" and "Clay is aesthetic and versatile material, with his various colors (white, red to coalblack)" that achieved percentage value 93%. Also. 13 experts that presents 87% affirmed that "Clay material can be recycled" and "Clay integration in contemporary architecture is economic". Moreover 80% of experts that present 12 professionals detected that "Clay material saves organic materials, as wood" and "Clay walls absorb pollutants" and "Clay can significantly resist fire". Experts that constitute 73% mentioned that "Clay characterize high-energy storage capacity: and "The possibility of creating decorations and engravings that suit modern architecture". It was revealed by 67% of respondents that comprise 10 experts "Clay considers energy saver material". In addition, it was noted by 9 experts that "Clay architecture upgrades heritage, tradition and cultural practice." and "Clay buildings characterize durability." Only 5 experts think that "Using clay leads to very robust and strong structures". These findings by respondents are identical to the benefits reviewed in the literature obtained and answers with few responses from experts and not relevant to the literature were excluded

4.1.3 Disadvantages of Clay Utilization in Contemporary Architecture

The professionals were asked to detect the disadvantages and barriers of using clay material in contemporary architecture and fifteen participators answered accordingly. Fifteen experts answered the section C of Delphi-questionnaire. The experts indicated to the disadvantages of clay utilization in contemporary architecture. Each expert responded according to his knowledge of the forms of attribution of the uses of clay in mud architecture. After that, the experts' answers were collected by mentioning each barrier of using clay in contemporary architecture, along with mentioning the number of experts who referred to each barrier. Table 4.3 shows disadvantages of clay utilization in contemporary architecture according to round one of Delphi technique.

Table 4.3: Disadvantages of Clay Utilization in Contemporary Architecture.

Round one of Delphi Technique	Number of Experts
Clay architecture can't resist earthquakes	13
Clay architecture less durable, structurally lower, and poor technically.	8
Clay walls require high wall thickness.	3
Misunderstanding, lack of awareness, and lack of skill amongst professionals, governments and all stakeholders.	12
Clay construction requires much time and labor	10
Inadequate clay construction technologies	10
Lack of training and courses on clay construction	7
Lack of interest by clients in the thermal comfort and aesthetic aspects provided by mud architecture	15
Absence of building standards and regulations.	13
Clay material has low tensile strength	14

Table 4.3 illustrates that all respondents affirmed the barrier of using clay is "Lack of interest by clients in the thermal comfort and aesthetic aspects provided by mud architecture" while

14 respondents think that “Clay material has low tensile strength”. 13 out of 15 experts think that “Clay architecture can't resist earthquakes” and “Absence of building standards and regulations”. 80% of replies that presented by answers by 12 experts indicated to “Misunderstanding, lack of awareness, and lack of skill amongst professionals, governments and all stakeholders”. 67 % of replies by 10 experts mentioned both of “Clay construction requires much time and labor” and “Inadequate clay construction technologies”. 8 out of 15 professionals in earth construction found “Clay architecture less durable, structurally lower, and poor technically”. Also, “Lack of training and courses on clay construction” was answered by only 7 experts by percentage 47%. Only three experts indicated that “Clay walls require high wall thickness”. These facts provided by experts were compared to literature review implemented in chapter two and answers with few responses from experts and not relevant to the literature were excluded.

4.2 DELPHI TECHNIQUE RESULTS (ROUND TWO)

In Round 2, the Delphi participators were introducing with a unified list of CFs determined in the round one. Each CF was coded in Table 4.4 according to and Form of clay utilization with symbol (CF-F) and each CF was coded in Table 4.5 according to benefit of clay utilization with symbol (CF-B) While each CF was coded in Table 4.6 according to disadvantage of clay utilization with symbol (CF-d), in order to facilitate better and easier comprehension by the participants.

They were then requested to order the CFs in order of priority, 1 being the most essential, and 10 being the least so in Forms of clay utilization list and were then requested to rank the CSFs in order of priority, 1 being the most essential, and 19 being the least so in clay benefit list while They were then requested to rank the CSF’s in order of priority, 1 being the most essential, and 10 being the least so in clay advantages list. The Round 2 questionnaire can be found in Appendix B, 8 out of the 10 participants returned their questionnaires in time. Due to time constraints, the researcher decided to progress the analysis of the data.

The CSF rankings in Round 2 are shown in Table 4.4, Table 4.5, Table 4.6 below.

In two round questionnaire, eight experts participate in questionnaire where each expert ranked each factor according to the significant of factor then their answers were summed

and according to sum column the least value of sum ranked as the most significant factor which took number one while the highest value of sum achieved the least significant factor as illustrated in Table 4.4, Table 4.5, Table 4.6

Table 4.4 Ranks the Forms of clay utilization in Contemporary Architecture according to the importance. It Can be noted that in round 2 of Delphi technique the most significant form of clay utilization are rammed earth architecture, compressed blocks and Integration 3D printing technique with clay architecture, cobs and adobe bricks.

Delphi technique could affirm the efficiency of 3d printing robotic in forming clay in contemporary architecture in which it can be promising technique to facilitate clay adoption in contemporary construction. Also, this technique can reduce labor and construction techniques. In addition to the high accurate in forming different shapes, decorations and patterns. Also, this technique allows integrating clay with other construction materials to improve structural and thermal properties of clay in contemporary architecture. Also, Delphi technique indicated to clay utilization in contemporary architecture in a form of rammed earth architecture.

Also, rammed earth according to Delphi experience considers a very beneficial contribution in contemporary architecture. Rammed earth is a technique of building walls in situ whereby a selected mixture of earth, aggregates is compressed in strata between forms. Each stratum is almost 15 cm (6 in) deep. while filling each form, another form is placed above it, and the operation repeats again. This is continued until the required wall height is attained. A wider range of soils are proper when a low quantity (almost 6%) of cement is integrated to the mixture.

The result, named as ‘SEB’, is an extremely durable and attractive masonry product with several advantages. The numerous benefits of building with rammed earth comprise superior thermal mass, temperature and noise control, strength and durability, low maintenance, fire proofing, load bearing and pest deterrence, as well as its beauty and the pleasure of building with a natural and environmentally sound material. Delphi experts indicated to significant of compressed clay blocks to be adopted in contemporary architecture. compressed blocks is a soil-cement mix is located in the compress room and compacted to form the block. The block compacted when a applying a force, leading to a reduction in the air voids and an

enhance in the density of material. The clay 's porosity will reduce. Earth Blocks have lower embedded energy and co2 emissions. Earth Blocks characterize a positive ecological influence after construction. Not Emit Toxic Gases One of the few construction materials that don’t release poisons gases is compressed clay blocks.

Table 4.4: Forms of Clay Utilization in Contemporary Architecture.

CODE(i)	**Round Two of Delphi Technique**	**Judge(j)**								**sum**	**Rank**
		1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	17	
CF-F1	Rammed Earth represented by rammed earth walls	1	1	3	2	1	4	2	3	17	2
CF-F2	Cob	6	4	4	9	6	5	3	9	46	4
CF-F3	Adobe bricks	4	5	5	8	4	3	8	10	47	5
CF-F4	Fired clay architecture	10	10	10	10	9	10	7	8	74	9
CF-F5	Plaster solutions	8	7	6	5	10	6	5	4	51	6
CF-F6	Compressed blocks	3	2	2	3	3	2	1	2	18	3
CF-F7	Integration 3D printing technique with clay architecture	2	3	1	1	2	1	4	1	15	1
CF-F8	Wattle and Daub	**9**	8	9	7	8	9	10	5	65	8
CF-F9	decoration using clay can be presented using Baked terracotta panels on earthen walls	5	6	8	6	5	8	6	7	51	6
CF-F10	Facade bricks	7	9	7	4	7	7	9	6	56	7

Table 4.5 Ranks the benefits of clay utilization in Contemporary Architecture according to the importance. It Can be noted that in round 2 of Delphi technique the most significant benefit of clay utilization is: Clay material can be recycled, It greatly controls humidity and heat, A natural material that is widely available, Using clay leads to very robust and strong structures. economic, Clay architecture upgrades heritage, tradition and cultural practice, Clay walls absorb pollutants, Clay architecture offers simple designs with high aesthetical value, Clay material saves organic materials, as wood. Clay material considers environmentally sustainable, unlimited designs, shapes, and surfaces using clay material and Clay considers energy saver material.

Clay can be recycled at any time due to its distinctive properties that make it a non-degradable material. Also, Clay characterizes a high thermal mass, meaning they can absorb a heat during the day and slowly emit it at night, assisting to maintain the house cooler. Clay can upgrade heritage and culture through its use in clay architecture and the use of engravings, ornaments and decorations that distinguish the country and express its culture and civilization.

Table 4.5: Ranks the Benefits of Clay Utilization in Contemporary Architecture.

CODE(i)	Round Two of Delphi Technique		Judge(j)								Rank
		1	**2**	**3**	**4**	**5**	**6**	**7**	8	sum	
CF-B1	Clay material considers environmentally sustainable.	1	6	19	17	5	1	18	13	80	11
CF-B2	Clay material saves organic materials, as wood.	11	7	6	18	5	17	6	11	80	10
CF-B3	Clay walls absorb pollutants.	2	8	14	16	6	16	8	12	82	8
CF-B4	A natural material that is widely available	11	1	7	9	7	18	9	4	66	3
CF-B5	It greatly controls humidity and heat	5	9	8	7	3	5	7	3	47	2
CF-B6	Clay material can be recycled	3	10	9	8	1	3	1	10	45	1
CF-B7	Clay integration in contemporary architecture is economic.	6	10	10	6	2	2	5	4	45	1

Table 4.5: Ranks the Benefits of Clay Utilization in Contemporary Architecture "Table Continued".

CF-B8	Using clay leads to very robust and strong structures	**11**	5	11	10	8	15	4	14	78	4
CF-B9	Clay considers energy saver material	17	4	1	1	18	4	10	9	64	13
CF-B10	Clay architecture offers simple designs with high aesthetical value.	4	19	12	15	16	14	3	15	98	9
CF-B11	Clay architecture upgrades heritage, tradition and cultural practice.	19	11	13	5	17	7	2	7	81	7
CF-B12	The possibility of creating decorations and engravings that suit modern architecture	18	3	5	14	9	8	15	5	77	12

Table 4.5: Ranks the Benefits of Clay Utilization in Contemporary Architecture “Table Continued”.

CF-B13	Clay is aesthetic and versatile material, with his various colors (white, red to black)	11	18	16	2	14	6	11	6	84	14
CF-B14	Unlimited designs, shapes, and surfaces using clay material	19	16	4	4	15	19	12	17	106	13
CF-B15	Clay characterize high-energy storage capacity	13	12	15	3	10	10	14	16	93	18
CF-B16	Clay can significantly resist Fire.	18	15	17	12	19	11	19	18	129	16
CF-B17	Clay buildings characterize durability.	16	14	3	13	13	13	13	8	93	17
CF-B18	The clay wall is an excellent sound insulator	11	17	18	19	11	9	16	19	120	15
CF-B19	Clay has low heat conductivity and characterize high efficient thermal insulation	15	13	2	11	12	12	17	1	83	6

Table 4.6 Ranks the disadvantages of clay utilization in Contemporary Architecture according to the importance. Table 4. Indicates that the most critical factors lead to limitation in using clay in contemporary architecture are : Clay architecture can't resist earthquakes, Clay architecture less durable, structurally lower, and poor technically, Misunderstanding, lack of awareness, and lack of skill amongst professionals, governments and all stakeholders, Clay walls require high wall thickness, Absence of building standards and regulations, Lack of training and courses on clay construction. Clay construction requires much time and labor, Inadequate clay construction technologies.

Buildings manufactured of clay considers heavy, poor and brittle. During seismic vibration clay walls generate large inertia forces, that they are disable to resist these vibrations , and consequently they collapse in sudden manner. The causes of being clay architecture less durable, structurally lower than concrete structure that is the mechanical properties of clay as tensile strength and compressive strength less than concrete material making clay less durable. Also,Delphi technique and literature relevant to the topic that reviewed showed lack in awareness and knowledge of clay architecture and their advantages in addition, lack of providing construction industry to adopt clay in contemporary architecture and shading. Moreover, it was noticed lack in academic studies and scientific researches to set regulations ,codes and standards to adopt clay as construction material in contemporary architecture for ideal utilization it . Clay consumes much time and labor during construction because it takes a long time to dry and cure, which can delay construction.

Table 4.6: The Disadvantages of Clay Utilization in Contemporary Architecture According to the Importance.

CODE(i)	Round Two of Delphi Technique	Judge(j)								Sum	RANK
		1	**2**	**3**	**4**	**5**	**6**	**7**	8		
CF-D1	Clay architecture can't resist earthquakes	1	5	1	5	10	10	1	1	34	1
CF-D2	Clay architecture less durable, structurally lower, and poor technically.	5	1	8	1	8	1	6	4	34	1
CF-D3	Clay walls require high wall thickness.	2	2	6	8	2	8	5	10	43	3
CF-D4	Misunderstanding, lack of awareness, and lack of skill amongst professionals, governments and all stakeholders.	4	4	4	10	9	2	2	2	37	2
CF-D5	Clay construction requires much time and labor	9	3	5	3	3	9	7	9	48	6
CF-D6	Inadequate clay construction technologies	3	10	7	7	7	3	10	3	50	7
CF-D7	Lack of training and courses on clay construction	7	7	10	4	1	7	3	7	46	5

Table 4.6: The Disadvantages of Clay Utilization in Contemporary Architecture According to the Importance "Table Continued.

CF-D8	Lack of interest by clients in the thermal comfort and aesthetic aspects provided by mud architecture	**8**	9	3	9	5	5	8	6	53	9
CF-D9	Absence of building standards and regulations.	10	8	2	2	4	6	4	8	44	4
CF-D10	Clay material has low tensile strength	6	6	9	6	6	4	9	5	51	8

4.3 IN- DEPTH INTERVIEWS FINDINGS

Interviews were conducted with three experts from different countries who have extensive knowledge and practical and academic experience in the use of concrete in contemporary architecture. The experts were selected for in-depth interviews based on their practical and academic experience in the relevant topic. Questions were asked to these experts related to the forms of use of concrete in contemporary architecture. And presenting views regarding the benefits and disadvantages of using concrete in contemporary architecture from a practical and scientific perspective. The lists for the second round of the Delphi technique were then presented to these experts to demonstrate the accuracy of the results obtained using the Delphi method.

4.3.1 Views of Expert (A) about Clay Utilization in Contemporary Architecture

Expert A was asked about the possible forms of using concrete in contemporary architecture. Expert A was also asked about the benefits and disadvantages of using concrete in contemporary architecture. Expert A was asked to have all his answers based on his practical

and academic experience in contemporary architecture. As for Expert A, he stated that the most important form of using clay in contemporary architecture is the modern technology that relies on three-dimensional printing in constructing clay buildings using clay on site. Expert A stated that this technology is a very modern field and contributes to the formation of clay in buildings in different shapes, engravings, and decorations. Distinctive, but this technology must take into account the type of soil used when 3D printing, as the source of the dirt has a major impact on the ability to form it due to the difference in soil properties from one source to another. the expert has exhibited the improvement of new 3D-printed clay bricks with complicated interior geometries. This technique overcomes, moving beyond simple interior patterns and decorations. The expert a mentioned that future studies in the field of 3D printing clay buildings, high-performance clay elements. In addition, the future technology of 3d printing will depend on both the structural and thermal performance of 3D-printed bricks. Also, Expert A provided this study a photo shows magnificent decorations and patterns of clay bricks using 3D printing.

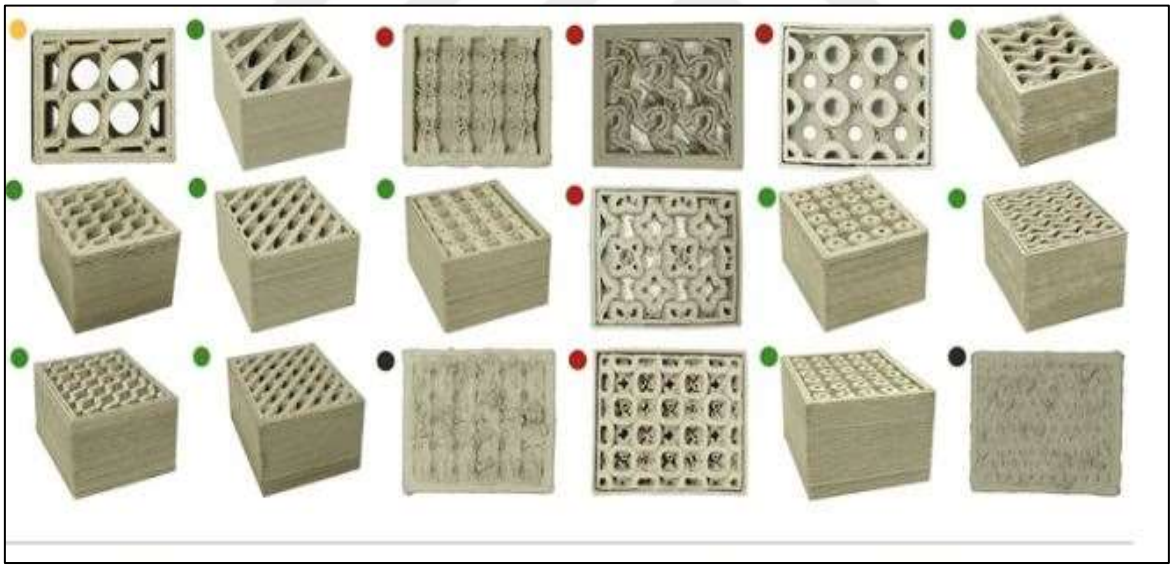

Figure 4.1: Magnificent Decorations and Patterns of Clay Bricks Using 3D Printing (Expert A).

Also, the expert talked about compressed blocks that are manufactured of clay soil. Expert A mentioned that Automated compressed earth blocks is manufactured of mixing of dry clay and sand and manufactures utilizing a mechanized hydraulically compressed brick device with numerous bricks shapes and expert at provided this study with forms of compressed blocks produced illustrated in figure 4.2. Moreover, the expert mentioned the benefits of

using this technique in contemporary architecture and indicated to its ultimate bearing capacity that presents 2/3 that of concrete blocks

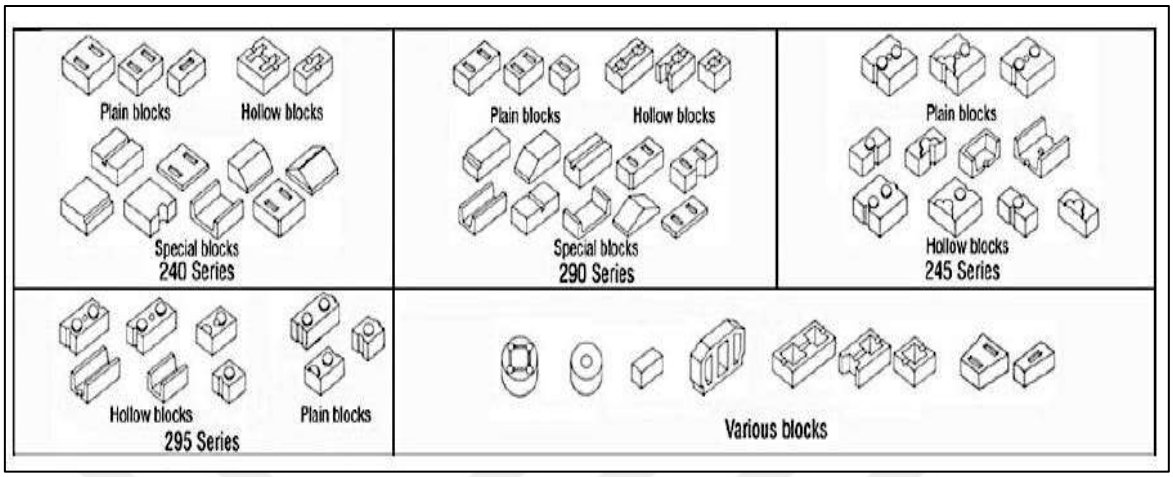

Figure 4.2: Form of Compressed Blocks (Expert A)

Moreover, Expert A showed that Clay blocks achieve lower cost than fired blocks and mansory blocks. Also, experts A showed that these compressed blocks can be enhanced by adding cement percentage to enhance its mechanical properties which achieves compressed and stabilized earth bricks. The compressive and tensile strength of these bricks is higher and its resist water significantly and achieve the energy demands of stabilized compressed raw clay bricks is three to five times least than the traditional fired bricks.

Moreover, Expert A mentioned that Rammed clay walls in contemporary architecture can enhance the acoustics indoor the building and can contribute to cool the structure using their high thermal mass to the utilize of rammed clay in contemporary residential projects shed lights in the material's variety and warmth.

Rammed earth construction is the design art and constructing structures, in particular walls, via ramming a mix of sand, gravel, silt, and clay into place between moulds. In contemporary modern architecture, cement is utilized as stabilizers to enhance the clay ’s stability. Figure 4.3 illustrate examples of rammed earth architecture provided by Expert A.

Figure 4.3: Examples of Rammed Earth Architecture

Expert A also shed light in novel brick facades in contemporary architecture are usually designed and constructed with considering simplicity. This pattern is attained via the utilize of clean lines and uncluttered surfaces. Brick is utilized not as the axial point of the facade but only as a background to shed light in another architectural components.

Expert A indicated to the form of clay utilization as clay plasters that are utilized greatly indoors and do not demand any chemical reaction, that enable them an environmental and healthy remedial strategy. The vegetable fibres and straw addition or even cellulose achieves a more unified texture and enhance area fixation. The colors gained are the clay natural shades, with no pigment addition. Expert A mentioned that constructing contemporary building integrating clay forms can be contributed to constructed rapidly, reduce both time execution and budget. Also, clay architecture achieves low cost in maintenance owing to resist clay products to hard weather factors, pests, vegetation created, and pollutants.

clay material considers Versatile in which Clay materials can be utilized for a wide of utilization. They can be utilized for walls, facades and ceilings in addition to parks and open spaces. Clay tiles and bricks can be utilized approximately any place and for all architectural patterns comprising for houses or, office or public structures.

Expert A insured that clay material is an Energy-efficient material due to their efficient insulation characteristics and their heat storage capability of storing heat and consequently clay materials assist to minimize the energy depletion of structures. Expert A thinks that clay material is Durable since they are robust, stable and, consequently, in particular durable; their serviceability is higher than 100 years. structures manufactured of clay specially tiles and bricks are resisted to the weather, earthquake and fire. Expert A illustrated that clay bricks characterize Aesthetic in which due to a high spread of available colors, patterns, geometries and surfaces, the potential designs numbers is approximately unlimited. Clay

bricks characterize with several colors include super white, classic red and coal-black. Available variants comprise tough, soft and glazed surfaces, elongated and spread patterns. Expert A explained that mud architecture is characterized by low maintenance costs and is economical because it is highly resistant to weather factors, fires and pollutants, in addition to the great property of insulating against heat and cold. Vegetables are also considered a sustainable material because they are available in abundance and are considered natural raw materials suitable for nature and humans. They are free of pollutants and thus guarantee a healthy environment. The expert stated some of the obstacles to using concrete in contemporary construction, which are its lack of resistance to moisture in addition to its tendency to rot due to the presence of pores that work to absorb water and thus cause structural damage. One of the most important disadvantages of using concrete in contemporary architecture is that it is weak in resistance to heavy loads and earthquake loads.In addition to low strength under tension .

4.3.2 Views of Expert (B) about Clay Utilization in Contemporary Architecture

Expert B showed that most of the studies are based on Adobe bricks in contemporary architecture. in which expert B illustrated that mechanical strength are gained for mixture of clay, sand, and a solution of bones glue .in addition flexural tensile resistance can be enhanced using hemp fibers addition. The thermal conductivity is enhanced using straw. Also, impregnation of clay brick surface with linseed oil can treat its surface. This technique makes the clay surface an excellent water resistance; it is handled with two strata of linseed oil. expert B stated that these clay products can be utilized successfully in contemporary architecture to get an eco- friendly, energy-efficient construction with a desirable influence on healthy, reducing pollution by minimizing concrete depletion.

Expert B provided photos of contemporary buildings adopted using Adobe brick in contemporary architecture illustrated in Figure 4.4.

Figure 4.4: Using Adobe Brick in Contemporary Architecture.

expert B mentioned other clay utilization in contemporary construction that is stabilized earth blocks that stabilized clay blocks may be utilized with no addition equipment. The transportation costs get minimized, since the SEB can be cast on the It characterize with low cost and availability of the soil. The two remarkable variations between SEB and the fired clay bricks are the quantity of energy utilized and the co2 emission. in which SEB bricks is more eco-friendly that fired brick type

Expert B also gave many examples around the world of the use of rammed earth in contemporary architecture. The building Chapel of Reconciliation in Germany is the first structure and built of rammed clay, and is considered the most novel instances of this construction method in the world. utilize of the rammed clay style requires compressing a humid earth mix including sand, gravel and clay into an exterior supported frame that constitute the wall section shape, resulting in a rigid earth wall. Expert B supported the example of rammed earth with actual photo illustrated in Figure 5.5 of building Chapel of Reconciliation.

Figure 4.5: Building Chapel of Reconciliation.

Expert B Rammed supported this form utilization by example of Earth Home by Paul Weiner which indicated that rammed earth experiencing renovation considering a sustainable material because it's natural, economic and introduces excellent thermal mass.

Figure 4.6: Earth Home by Paul Weiner.

Expert B indicated that Earthen structure is considered non-toxic, non-polluting and breathes. The novel earth building develops safer, more people friendly structures and sustainable structures. It is extremely low in energy depletion, and very comfortable for living.

Expert B indicated to Terracotta as form of clay utilization in contemporary architecture and explained that the term id is derived from two Italian team, "terra", which means earth, and "cotta", indicated to baked. It indicates to an oxidized clay. The utilization of clay panels to

the facade buildings is named Terracotta Cladding. This amazing substance provides a charming integration of durability and sustainability. Terracotta is existed in a various of forms, colours and measurements. This permits architects to adopt visually stunning facades designation. It is famous for its multi utilizations, integrating well with conventional in addition to contemporary architecture styles. This enable it to be best selection for both commercial and residential buildings. The experts indicated to the popularity of this material due to its thermal insulation, weather resistance and low maintenance requirements. Expert B supported these facilities using example of structure adopted terracotta in the facades illustrate in Figure 4.7

Figure 4.7: Using Example of Structure Adopted Terracotta in the Facades.

Experts B stated that Cob is a form of clay utilization in contemporary construction technique that is an earth construction technique depends on building technique that can be an alternative to construct new houses in developing countries. Cob construction can be suitable selection in rural regions, where worker is a less limited source comparing to monetary capital, and the materials required are greatly available. The cob method depends

on mixing clay, sand, straw and water that can give the builder the choice to integrate several materials and to develop a various shape. Also, Expert B stated that this technique can reduce GHG emission more than concrete structures. Moreover, Expert B mentioned the barrier of adopting this technique represented by shortage for people to see and experience, and a general limited awareness on how to work with cob method. Expert B provides a photo illustrated in Figure 4.8 as example of using Cob in contemporary architecture.

Figure 4.8: Example of Using Cob in Contemporary Architecture.

Exerts B indicated to some disadvantages of using clay as greatly susceptible to moisture, Require skilled labor for right execution. clay bricks are fabricated utilizing old technology and there is no tests to insure quality. Most bricks that are fabricated with old technology are low in quality with low compressive resistance and low tensile strength. This technique is not proper for multi-storey structures.

4.3.3 Views of Expert (C) about Clay Utilization in Contemporary Architecture

Expert **(**C**)** Indicated to the barriers and limitations in using clay in contemporary architecture in which the expert stated that the clay elements are poor to resist lateral loads as earthquakes, Also, the expert mentioned that implementing wall structures required Clay walls with high thickness moreover expert C revealed that there lack in standards and

provisions that adopts mud architecture addition to limitations in work shop to have experience and knowledge about mud architecture. Expert C also the advantages of using clay in modern architecture.

Clay material can be recycled, it greatly controls humidity and heat, A natural material that is widely available, using clay leads to very robust and strong structures. economic, Clay architecture upgrades heritage, tradition and cultural practice, Clay walls absorb pollutants, Clay architecture offers simple designs with high aesthetical value, Clay material saves organic materials, as wood. Clay material considers environmentally sustainable, Unlimited designs, shapes, and surfaces using clay material and Clay considers energy saver material. Expert C stated that clay structures can be demolished and recycled, and they are considered strong structures when combined with reinforcing materials such as cement and high-resistant materials. In addition, they are economical because they are available in abundance, and due to their durability, their maintenance costs are low. The clay can also absorb pollutants due to its porosity property. It has a sustainable, environmentally friendly material that gives warmth in winter and coolness in summer, so it is preferable to use it in hot areas.

5. CONCLUSIONS

5.1 SUMMARY

In this study, the extent of the possibility of using concrete in contemporary architecture was addressed. To achieve the objectives of the research, the study was divided into three sections, which are the forms of using concrete in contemporary architecture, the benefits of using concrete in contemporary architecture, and the disadvantages of using concrete in contemporary architecture.

The research methodology was based on collecting the literature in sections related to the topic. Then the Delphi method was applied by adopting two rounds to determine the most important factors for the use of concrete in contemporary architecture. After that, in-depth interviews were conducted with three experts and the results of the literature, the results of the Delphi method, and the results related to the interviews were compared to reach the final results.

5.2 CONCLUSION

5.2.1 Clay Contributions as Forms of Construction Techniques in Contemporary Architecture.

The results of the forms of uses of clay in contemporary architecture were collected according to the three methods adopted in the study, as in Table 5.1. The three methods, which are the literature review, the Delphi technique, and in-depth interviews, agreed that clay can be used effectively in contemporary architecture according to the following forms of uses:

a. These three methods agreed that the construction techniques for using clay in contemporary architecture are the use of 3d- printing in contemporary clay architecture, the use of earth-rammed architecture, the use of compressed clay blocks, adobe bricks and terracotta panels

b. literature review, Delphi technique and in depth interviews could affirm the efficiency of 3d printing robotic in forming clay in contemporary architecture in which it can be promising technique to facilitate clay adoption in contemporary construction. Also, this

technique can reduce labor and construction techniques. In addition to the high accurate in forming different shapes, decorations and patterns .Also, this technique allows integrating clay with other construction materials to improve structural and thermal properties of clay in contemporary architecture.

c. Also, study methods indicated to clay utilization in contemporary architecture in a form of rammed earth architecture. Also, rammed earth according to Delphi experience considers a very beneficial contribution in contemporary architecture. The numerous benefits of building with rammed earth comprise superior thermal mass, temperature and noise control, strength and durability, low maintenance, fire proofing, load bearing and pest deterrence, as well as its beauty and the pleasure of building with a natural and environmentally sound material.

d. Study methods indicated to significant of compressed clay blocks to be adopted in contemporary architecture. compressed blocks is a soil-cement mix is located in the compress room and compacted to form the block. The block compacted when a applying a force, leading to a reduction in the air voids and an enhance in the density of material. The clay 's porosity will reduce. Earth Blocks have lower embedded energy and co2 emissions. Earth Blocks characterize a positive ecological influence after construction. Not Emit Toxic Gases One of the few construction materials that don't release poisons gases is compressed clay blocks. techniques also affirmed the efficiency of adobe bricks to utilize them successfully in contemporary architecture to get an eco- friendly, energy-efficient construction with a desirable influence on healthy, reducing pollution by minimizing concrete depletion.

e. three methods showed the efficiency of Terracotta panels to the facade buildings. This amazing substance provides a charming integration of durability and sustainability. Terracotta is existed in a various of forms, colours and measurements. This permits architects to adopt visually stunning facades designation. It is famous for its multi utilizations, integrating well with conventional in addition to contemporary architecture styles. This enable it to be best selection for both commercial and residential buildings. The study indicated to the popularity of this material due to its thermal insulation, weather resistance and low maintenance requirements.

According to what was mentioned previously, it can be concluded that this study provided the construction sector and architectural designers with the most important useful contributions to the forms and techniques of using clay in contemporary architecture for adoption in the design and implementation of buildings.

Table 5.1: Clay Utilization in Contemporary Architecture According to the Study Methods Consensus.

CODE(i)	Clay utilization in contemporary architecture	Literature	Delphi	In-depth interviews
CF-F1	Rammed Earth represented by rammed earth walls	✓	✓	✓
CF-F2	Cob	✓	✓	✓
CF-F3	Adobe bricks	✓	✓	✓
CF-F4	Fired clay architecture	✓	✓	
CF-F5	Plaster solutions	✓	✓	
CF-F6	Compressed blocks	✓	✓	✓
CF-F7	Integration 3D printing technique with clay architecture	✓	✓	✓
CF-F8	Wattle and Daub	✓		
CF-F9	decoration using clay can be presented using Baked terracotta panels on earthen walls	✓	✓	
CF-F10	Facade bricks	✓		

5.2.2 Beneficial Contributions as Forms of Construction Techniques in Contemporary Architecture.

Environmental Friendliness: using clay in buildings making them more eco-friendly sustainable than other contemporary structures . Their production usually demands low energy and results in lower GHG emission to the fabricating of traditional concrete buildings .

Energy Efficiency: structures built with clay construction have optimum thermal mass, which means absorbing and retain heat, assisting to preserve a stable indoor temperature. This feature can minimize the requirement for artificial heating or cooling, consequently reducing energy depletion and budgets.

Cost-Effectiveness: The major material for mud buildings , clay , is usually locally available and cheap. The producing these types can reduce the cost compared to purchasing standard construction materials, in particular in fields where these substances require to be transmitted over long distances.

Low Technique Demand: production of mud architecture can be executed utilizing simple and low-cost machines, or even hand made, enabling to be more desirable even in far areas or developing countries with low resources.

Aesthetic look: mud architecture characterize a natural and earthy appearance, that is aesthetically pleasing and can be left exposed without the need for plaster or paint, further reducing construction costs and environmental impact.

Thermal and Acoustic Insulation: The density and composition of clay provide good sound insulation and help in maintaining a comfortable indoor climate.

Humidity Regulation: Earthen materials have the ability to absorb and release moisture, which can help in regulating indoor humidity levels, contributing to a more comfortable living environment.

Cultural and Traditional Relevance: In several regions of the world, clay construction is a conventional method. Adopting compressed blocks can assist maintain these cultural practices while still introducing modern structural strength and conveniences.

Flexibility in Design: compressed blocks can be formed in numerous patterns and dimensions, permitting for architectural flexibility and creativity in designs of building.

Recyclability: compressed blocks can be recycled to the earth, reducing ecological effect.

These beneficial contributions of clay in contemporary architecture can motivate construction industry and architectural designers to adopt clay in future contemporary architecture.

5.2.3 Barriers of Clay Utilization in Contemporary Architecture

The challenges facing the use of clay in contemporary architecture were studied to educate the construction sector and architectural designers about these obstacles to avoid, deal with, and solve any potential damages. It was agreed upon by previous studies, the Delphi method, and in-depth interviews that buildings made of clay cannot withstand lateral loads such as earthquakes. Clay architecture can't resist earthquakes, Clay architecture less durable, structurally lower, and poor technically, Misunderstanding, lack of awareness, and lack of skill amongst professionals, governments and all stakeholders, Clay walls require high wall thickness, Absence of building standards and regulations, Lack of training and courses on clay construction. Clay construction requires much time and labor, Inadequate clay construction technologies. The construction sector and architectural designers' knowledge of these obstacles is very important to find remedial solutions and improve the use of clay in clay architecture.

5.3 RECOMMENDATIONS

a. This study provided a comprehensive investigation of the forms of use of clay in contemporary construction. On the other hand, the use of clay in contemporary construction is limited, so it is recommended to conduct more research studies and practical applications to integrate clay in contemporary architecture.

b. These studies have shown the challenges facing the use of clay in contemporary construction, the most important of which are the lack of resistance of clay buildings to earthquake loads and weak mechanical properties. Therefore, the construction sector and academic studies are recommended to conduct the necessary research to improve

the mechanical properties of clay and improve its performance in resisting earthquakes by combining it with other materials with high resistance to improve its resistance to the possibility of using it in contemporary construction.

c. Given the beneficial contributions of clay to sustainability, improving thermal comfort, adding aesthetics, and other benefits to contemporary buildings, the construction sector is recommended to spread awareness about adopting the use of clay in architectural design and implementation.

REFERENCES

A Ángel" Computational analysis of the thermal behavior on a silica (SiO2) aerogel coating for applications in the construction industry" 2019.

A. G. Muazu, H. Z. Alibaba, The Use of Traditional Building Materials in Modern Methods of Construction, IJESTR, Volume – 2, Issue – 6, (2017), pp. 30-40.

Abdulrasool Thamer Abdulrasool" Sustainable Materials Used as Lightweight Aggregate :(An Overview)" 2022.

Adler, M. and Ziglio. E. (1996). Gazing into the oracle: The Delphi Method and its application to social policy andpublic health. London: Jessica Kingsley Publishers.

Akinyele, J. O., Igba, U. T., Ayorinde, T. O., & Jimoh, P. O. (2020). Structural efficiency of burnt clay bricks containing waste crushed glass and polypropylene granules. Case Studies in Construction Materials, 13, e00404.

Almssad, A., Almusaed, A., & Homod, R. Z. (2022). Masonry in the context of sustainable buildings: A review of the brick role in architecture. Sustainability, 14(22), 14734.

Araya-Letelier, G.; Antico, C.; Federico, W.; María, J.; Gonzalez Retamal, R. Eco-bricks: A sustainable substitute for construction material. Rev. Construcción 2017, 16, 518–526. Available online: https://www.redalyc.org/articulo.oa?id=127654962016

Ashley nicolle gramlich "a concise history of the use of the rammed earth building technique including information on methods of preservation, repair, and maintenance" 2013.

Attalla, R. The Technology of Mudbricks from the Sacred Architecture in Ancient Egypt to the Green House Revolution (Case Study of Luxor City, Egypt). Int. J. Adv. Sci. Technol. 2020, 29, 1264–1277.

Auroville Earth Institute. Earth Based Technologies, (2009). Available on: www.earthauroville.com/maintenance/uploaded_pics/4-cseb-en.pdf (Leo Espinosa,2017), Rammed earth design .https://www.instagram.com/p/CL9yP3qMUpo/

Beckett, C. T. S., Jaquin, P. A., & Morel, J. C. (2020). Weathering the storm: A framework to assess the resistance of earthen structures to water damage. Construction and Building Materials, 242, 118098

Benyoucef, M. Y. (2020). Contemporary architecture design of clay material-ecological alternatives for individual houses in the sahara desert. In Materials Science Forum (Vol. 1005, pp. 57-64). Trans Tech Publications Ltd.

Costa, C., Cerqueira, Â., Rocha, F., & Velosa, A. (2018). The sustainability of adobe construction: past to future. International Journal of Architectural Heritage.

Daniel, A. A., Benjamin, G. K., & Tali, J. O. (2018). Adopting stabilized earth construction to address urban low-cost housing crisis in Jos, Nigeria.

Dayaratne, R. (2010). Reinventing traditional technologies for sustainability: contemporary earth architecture of Sri Lanka. Journal of Green building, 5(4), 23-33.

Delbeq, A., Van de Ven, A., and Gustafson, D. H. (1975). Group techniques for program planning: A guide to nominal group and Delphi processes. Glenview, USA: Scott, Foresman and Company.

Djamil, B. (2016). Sun-dried clay for sustainable constructions. International Journal of Applied Engineering Research, 11(6), 4628-4633.

El Halim et al., J. Mater. Environ "Mineralogy and firing characteristics of clayey materials used for ceramic purposes from Sale region (Morocco)" 2018.

Ghada Ghalib Abdulwahab" Employing Sustainable Environmental Technologies in Raising the Efficiency of the Building Ecosystem" 2021.

Ghita El Idrissi Semlali" IMPROVEMENT OF FIRED CLAY BRICKS PROPERTIES FOR SUSTAINABLE CONSTRUCTIONS" 2018.

Ivyleen C. Bernardo-Arugay "Evaluation of Linamon Red Clay, Salvador Black Cinder and Kapatagan Diatomaceous Earth of the Southern Philippines" 2023.

JAMAL, H, (2017) Advantages and Disadvantages of clay bricks.https://www.aboutcivil.org/bricks-advantages-disadvantages-uses.html

Kankao Oumla Oumar" Mineralogical, Geochemical Characterization and Physicochemical Properties of Kaolinitic Clays of the Eastern Part of the Douala Sub-Basin, Cameroon, Central Africa" 2022.

Loosemore, M. (1999). International construction management research: cultural sensitivity in methodological design. Construction Management & Economics, 1999 - Taylor & Francis, 17:5, 553-561, DOI: 10.1080/014461999371178 To link to this article: https://doi.org/10.1080/014461999371178

M S S Lima[1], "Red mud application in construction industry: review of benefits and possibilities" 2017.

Mack, N., Woodsong, C., MacQueen, K. M., Guest, G. and Namey, E. (2005). Qualitative research methods: A data collector's field guide. USAID, Family Health International, North Carolina, USA.

Maini Satprem 1999. Seminar on Earth Architecture at Alliance Françoise De Colombo, Conducted by Auroville Building Center, India.

Marina Rabelo Brito " Evaluation of the Properties of Adobe Blocks with Clay and Manure" 2023.

N V Gontar" Technological innovations in the proactive modernization strategy of a construction company (by the example of Tandem group of companies)" 20

N. Nadarajah. Development of concrete 3D printing, Thesis (Mater of Science in Building Technology), Aalto University, (2018), p. 1.

Narendhran "Envisaging Sustainable Building Materials for Earthen Construction Practices" 2023.

Niedziółka Rybak-" Utilization of Jordanian Bentonite Clay in Mortar and Concrete Mixtures" 2022.

Partridge S, Barn O. Wattle & daub - Lowimpact.org [Internet]. Lowimpact.org. [cited 6 March 2016]. Available from: http://www.lowimpact.org/lowimpacttopic/wattle-daub/

Pons, J. J., Penadés-Plà, V., Yepes, V., & Martí, J. V. (2018). Life cycle assessment of earth-retaining walls: An environmental comparison. Journal of Cleaner Production, 192, 411-420.

Priyanka Danal, Suman Sharma ”International Journal of Advance Research, Ideas and Innovations in Technology, Mud Architecture”2017. Neeraj Kumari and Chandra Mohan" Basics of Clay Minerals and Their Characteristic Properties" 2021.

Sruthi, G. S. (2013). Mud architecture. International Journal of Innovative Research in Science, Engineering and Technology, 2(1), 47-49.

Villeda-Muñoz, G.; Castañeda-Miranda, A.; Pless, R.C.; Vega-Durán, J.T.; Pineda-Piñón, J. Clay-Brick Firing in a High-Temperature Solar Furnace. Ing. Investig. Tecnol. 2011, 12, 395–408.

Wasp,(2018). 3D-printed Gaia house is made from biodegradable materials, https://www.dezeen.com/2019/02/27/gaia-wasp-3d-printed-house-biodegradable-video/

Yang shi ,2016, Decrepit cave transformed into a beautiful modern home in China https://inhabitat.com/amazing-transformation-of-a-decrepit-cave-into-a-beautiful-modern-home/cave-house-by-hypersity-architects-2-2/

Z. Malaeb, H. Hachem, A. Tourbah, T. Maalouf, N. El Zarwi, F. Hamzeh, 3D concrete printing: machine and mix design, IJCIET, Volume 6, Issue 6, (2015), pp. 14-22

Zami, M. S. (2020). A conceptual framework outlining factors affecting the acceptance of earth as a sustainable building material in the United Kingdom. European Journal of Sustainable Development, 9(3), 241-241.

APPENDIX

DELPHI QUESTIONNAIRE

A.1 RESEARCH TOPIC: CONTEMPORARY BUILDING TECHNICS USING CONVENTIONAL MATERIALS, OF CLAY AND MUD

Researcher: Wiam AL-Jreibi

Preamble

This study sheds light on the use of clay architecture in modern architecture. This study discusses the forms, applications and techniques of using clay in contemporary architecture. This study also addresses the benefits resulting from the use of clay in modern architecture by discussing the benefits of sustainability. Benefits Economic, structural, artistic and aesthetic benefits. This study also discusses the obstacles that limit the use of concrete in contemporary architecture.

In this research, the Delphi method will be used to generate lists comprise the following:

1- the first list contains applications and techniques of using clay in contemporary architecture

2- the second list comprise the benefit of using clay in contemporary architecture from different aspect: sustainability, economic; aesthetic and structure technical properties.

The research data – i.e. opinions from experts in the construction industry – will be collected by means of several rounds of questionnaires, which generates a series of qualitative and quantitative data for analysis. The analysis findings will then determine the form and content of subsequent questionnaires, and so on until the group opinion is formed and is stable.

The Delphi method will be conducted in three rounds, as outlined below.

ROUND 1: Brainstorming of lists

ROUND 2: Ranking the statements of lists

Participating in this Study

You have been selected as a member of the Delphi expert panel. Over the next few weeks, you will be asked to complete three rounds of questionnaires. At the end of this period, the results of the questionnaires will be made available to you as a token of gratitude for your contribution.

Your participation is on a voluntary basis. Below are the conditions of voluntary participation:

- Confidentiality.
- Anonymity.
- Not asked to divulge any business-sensitive information.

The 2-page questionnaire can be found overleaf. The questionnaire should take no more than 30 minutes to complete.

Kindly return the completed questionnaire within 7 days of receiving the questionnaire. Many thanks in advance for your time and contribution. If you have any questions about the research, please do not hesitate to contact the undersigned.

Kind regards,

Wiam AL-Jreibi

ROUND 1 – BRAINSTORMING

Please fill these personal questions :

- Name:
- Years of experience in Architecture design :
- Occupation:
- Do you have experience in mud architecture: Yes ☐ No ☐

Please list at least 5 the most efficient application of clay as construction material in contemporary architecture comprising forms and techniques of using clay as construction material in contemporary architecture.

App 1: _____

_____

App 2: _____

_____

App 3: _____

_____

App 4: _____

_____

App 5: _____

_____

other: _____

_____

Please list at least 5 the most benefit of using clay as construction material in contemporary architecture related to the following aspects :sustainability, economic, structure and aethestic

benefit 1: _____

_____

benefit 2: _____

_____

benefit 3: _____

_____

benefit 4: _____

_____

benefit 5: _____

_____

other: _____

_____

_____

_____

Please list at least 5 the most barriers that limits using clay as construction material in contemporary architecture

barrier 1: _____

_____

barrier 2: _____

_____

barrier 3: _____

_____

barrier 4: _____

_____

barrier 5: _____

_____

other: _____

_____

_____

_____

DELPHI QUESTIONNAIRE – ROUND 2

Research topic: Critical factors for the clay employment in contemporary architecture

Researcher: wiam

Preamble
Thank you for completing your Round 1 Delphi questionnaire. I received a 60% response.
rate from all seven participants, which is excellent. Please find below some charts describing the demography and profile of the Delphi participants.

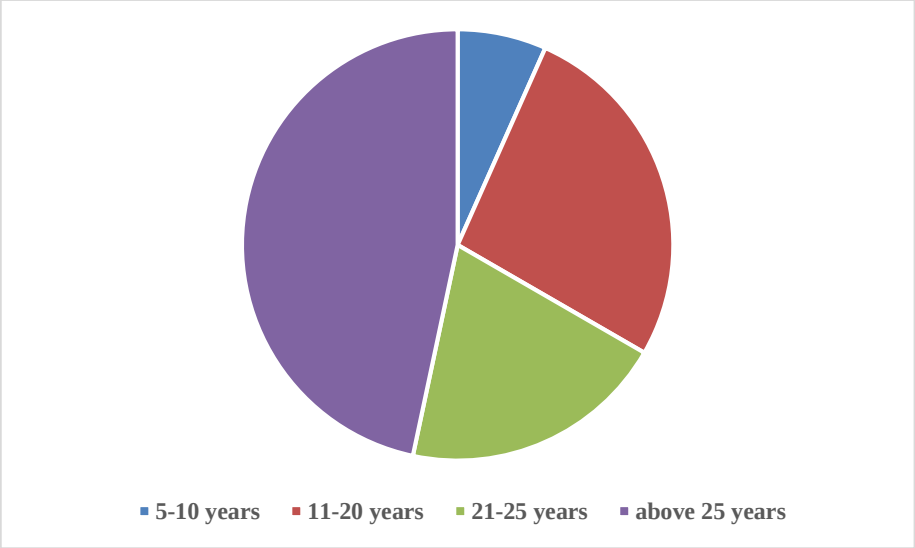

Figure A.1: Experience of Delphi Participants

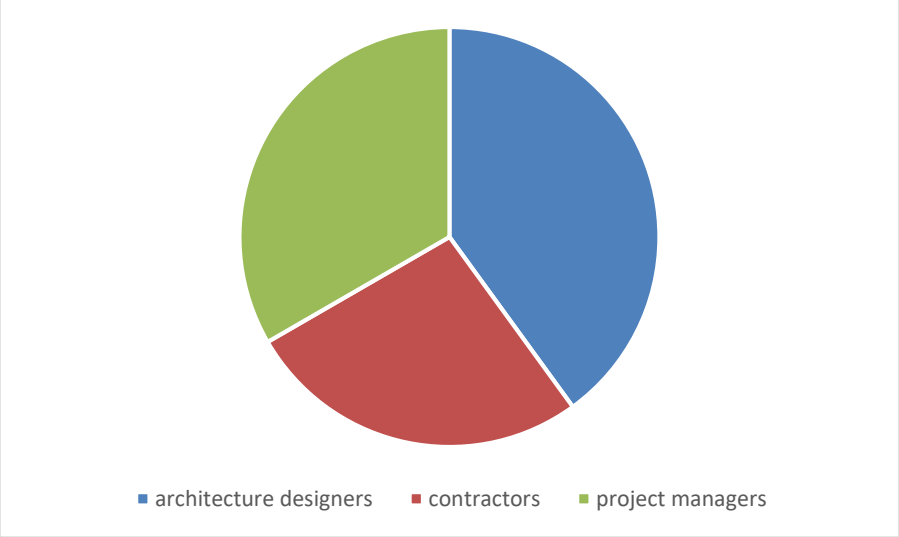

Figure A.2: Occupation of Delphi Participants.

Figure A.3: Involvement of Delphi Participants in mud Architecture.

In Round 2 Delphi we will review the results of Round 1 Delphi and attempt to rank the critical factors (CFs) in order of importance. The rankings will then be analyzed statistically to measure the level of consensus between all Delphi participants. Kindly return the completed questionnaire within 7 days of receiving the questionnaire.

Many thanks in advance for your time and contribution. If you have any questions about the research, please do not hesitate to contact the undersigned.

Kind regards,

Wiam AL-Jreibi

Round 1 Delphi Results

In Round 1 Delphi, the participants identified a number of common Critical Factors (CF's) for clay utilization in contemporary architecture. These CF's correlate well with existing literature and research and are listed below.

Table A.1: Forms of Clay Utilization in Contemporary Architecture.

CODE	Round one of Delphi Technique
CF-F1	Rammed Earth represented by rammed earth walls
CF-F2	Cob
CF-F3	Adobe bricks
CF-F4	Fired clay architecture
CF-F5	Plaster solutions
CF-F6	Compressed blocks
CF-F7	Integration 3D printing technique with clay architecture
CF-F8	Wattle and Daub
CF-F9	decoration using clay can be presented using Baked terracotta panels on earthen walls
CF-F10	Facade bricks

Table A.2: Benefits of Clay Utilization in Contemporary Architecture.

CODE	Round one of Delphi Technique
CF-B1	Clay material considers environmentally sustainable.
CF-B2	Clay material saves organic materials, as wood.
CF-B3	Clay walls absorb pollutants.
CF-B4	A natural material that is widely available
CF-B5	It greatly controls humidity and heat

Table A.2: Benefits of Clay Utilization in Contemporary Architecture "Table Continued".

CF-B6	Clay material can be recycled
CF-B7	Clay integration in contemporary architecture is economic.
CF-B8	Using clay leads to very robust and strong structures
CF-B9	Clay considers energy saver material
CF-B10	Clay architecture offers simple designs with high aesthetical value.
CF-B11	Clay architecture upgrades heritage, tradition and cultural practice.
CF-B12	The possibility of creating decorations and engravings that suit modern architecture
CF-B13	Clay is aesthetic and versatile material, with his various colors (white, red to black)
CF-B14	Unlimited designs, shapes, and surfaces using clay material
CF-B15	Clay characterize high-energy storage capacity
CF-B16	Clay can significantly resist Fire.
CF-B17	Clay buildings characterize durability.
CF-B18	The clay wall is an excellent sound insulator
CF-B19	Clay has low heat conductivity and characterize high efficient thermal insulation

Table A.3: Disadvantages of Clay Utilization in Contemporary Architecture.

Code	Round one of Delphi Technique
CF-D1	Clay architecture can't resist earthquakes
CF-D2	Clay architecture less durable, structurally lower, and poor technically.
CF-D3	Clay walls require high wall thickness.
CF-D4	Misunderstanding, lack of awareness, and lack of skill amongst professionals, governments and all stakeholders.
CF-D5	Clay construction requires much time and labor
CF-D6	Inadequate clay construction technologies
CF-D7	Lack of training and courses on clay construction
CF-D8	Lack of interest by clients in the thermal comfort and aesthetic aspects provided by mud architecture
CF-D9	Absence of building standards and regulations.
CF-D10	Clay material has low tensile strength

ROUND 2 – RANKING OF CSF's

Please carefully rank the CF's listed in the previous page IN Table 1, Table 2 Table 3 in order of importance (1 – most essential, 10– least essential). Critical Factor Rank (1 – 10).

where forms of clay utilization in contemporary architecture were coded as the following example :CF-d1, CF symbolizes to critical factor while F symbolize to critical

factor according to form of clay utilization in contemporary architecture and the number one refers to the number of the critical factor.

Table 2 in order of importance (1 – most essential, 19– least essential). Critical Factor Rank (1 – 19).) where benefits of clay utilization in contemporary architecture were coded as the following example :CF-b, CF symbolizes to critical factor while F symbolize to critical factor according to benefit of clay utilization in contemporary architecture and the number one refers to the number of the critical factor.

Table 3 in order of importance (1 – most essential, 10– least essential). Critical Factor Rank (1 – 10) where forms of clay utilization in contemporary architecture were coded as the following example :CF-D1, CF symbolizes to critical factor while F symbolize to critical factor according to disadvantages of clay utilization in contemporary architecture and the number one refers to the number of the critical factor.

Thank you for completing the Round 2 Delphi questionnaire.

Please return the completed questionnaire to the following address.

Wiam AL-Jreibi

Table A.4: Forms of Clay Utilization in Contemporary Architecture.

CODE	Rank(1-10)
CF-F1	
CF-F2	
CF-F3	
CF-F4	
CF-F5	
CF-F6	
CF-F7	
CF-F8	
CF-F9	
CF-F10	

Table A.5: Benefits of Clay Utilization in Contemporary Architecture.

CODE	Rank(1-19)
CF-B1	
CF-B2	
CF-B3	
CF-B4	
CF-B5	
CF-B6	
CF-B7	
CF-B8	
CF-B9	
CF-B10	
CF-B11	
CF-B12	
CF-B13	
CF-B14	
CF-B15	
CF-B16	
CF-B17	
CF-B18	
CF-B19	

Table A.6: Disadvantages of Clay Utilization in Contemporary Architecture.

Code	Rank(1-10)
CF-D1	
CF-D2	
CF-D3	
CF-D4	
CF-D5	
CF-D6	
CF-D7	
CF-D8	
CF-D9	
CF-D10	