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Numerical study of brick using hybrid genetic algorithm

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الاية القرانية

بسم الله الرحمن الرحيم

(هُوَ الَّذِي أَنزَلَ عَلَيْكَ الْكِتَابَ مِنْهُ آيَاتٌ مُّحْكَمَاتٌ هُنَّ أُمُّ الْكِتَابِ وَأُخَرُ مُتَشَابِهَاتٌ ۖ فَأَمَّا الَّذِينَ فِي قُلُوبِهِمْ زَيْغٌ فَيَتَّبِعُونَ مَا تَشَابَهَ مِنْهُ ابْتِغَاءَ الْفِتْنَةِ وَابْتِغَاءَ تَأْوِيلِهِ ۗ وَمَا يَعْلَمُ تَأْوِيلَهُ إِلَّا اللَّهُ ۗ وَالرَّاسِخُونَ فِي الْعِلْمِ يَقُولُونَ آمَنَّا بِهِ كُلٌّ مِّنْ عِندِ رَبِّنَا ۗ وَمَا يَذَّكَّرُ إِلَّا أُولُو الْأَلْبَابِ).

صدق الله العلي العظيم

سورة آل عمران : الآية ((7))

الإهداء

إلى صاحب السيرة العطرة، والفكر المُستنير؛

فلقد كان له الفضل الأوَّل في بلوغي التعليم العالي

(والدي الحبيب)، أطال الله في عُمره.

إلى من وضعتني على طريق الحياة، وجعلتني رابط الجأش،

وراعتني حتى صرت كبيرًا

(أمي الغالية)، طيَّب الله ثراها.

إلى إخوتي؛ من كان لهم بالغ الأثر في كثير من العقبات والصعاب.

إلى جميع أساتذتي الكرام؛ بالأخص مسؤول البحث

(Prof. Dr. Mohammed Al- dujaili) مما له فضل ومواقف رائعه معي و ممن لم يتوانوا في مد يد العون لي

أُهدي إليكم بحثي هذا.

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Chapter One: Introduction

1. Introduction

Since ancient times, man has tried to improve its comfort within buildings by improving the thermal inertia and minimize the equivalent thermal conductivity of the envelope of building. He increased the thickness, changed the geometry of the outer wall and tried several building materials to reduce temperature fluctuation for indoor environment in both summer and winter. The installation of heating and air conditioning to seek wellness in homes, offices and public places has created high energy consumption and consequently, increased earth pollution. In the worldwide energy crisis, energy saving has become a focusing cared topic by every county over the world. In Algeria a high rate of consumption of electrical energy is noticed during recent years [1].

The improved standard of living of Algerian family as well as the coming of Ramadan in the warmer months of the year has encouraged people to investigate their money to improve their comfort within habitats, offices and mosques. Excessive installation of air conditioning systems at different points of the country has increased the peak of the national grid, and huge losses were claimed by citizens during the year 2012 due to voltage drops and cuts in electricity. The previous researches have shown that the use of Phase Change Materials (PCM) in buildings increases considerably the thermal inertia of the walls. The PCM, introduced into the building envelopes, absorbs a large quantity of heat during a hot day and fuses gradually in an isothermal way to prevent the entrance of heat inside housing environments. During the night, the temperature decreases above the melting point of the PCM. Therefore, PCM releases heat into building envelope and becomes solid again. Thus, it can start a new cycle of melting/solidification during the following hours. Several studies have been conducted to improve the living conditions inside closed areas. Japing Sun [2] has studied a concrete hollow brick with four rectangle enclosures to minimize the equivalent thermal conductivity (ETC) in the constraint of variable shape and position parameters. The optimization obtains 21.69% improvement on the ETC.

Also, a comprehensive numerical study of the equivalent thermal conductivity of a multi-holed clay brick has been conducted by L.P. Li et al [3]. 50 kinds of combination of holes and arrangements are examined. The indoor–outdoor temperature difference varies from 50 °C to 20 °C and the effects of following factors are studied in details: the hole surface radiation, the width-wise and length-wise hole numbers, and the indoor–outdoor temperature difference. The optimum configuration is found which has five length-wise holes, four width-wise holes and all the holes are from bottom to top in the depth direction of a brick. Its equivalent thermal conductivity is 0.419 W/(m K), which is only 53.1% of solid clay of which it is made. Ammar Bouchair [4] has proposed a theoretical model to study the steady state thermal behavior of fired clay hollow bricks for enhanced external wall thermal insulation. The basic brick units used for the investigation are small-size and big-size bricks. Computer modeling and calculations performed, for steady state conditions, show that the increase in hollow brick cavity height contributes to the improvement of the overall thermal resistance of the order of 18–20%. The improvement could significantly increase to the range of 88.64% and 93.33%, if the bricks used are injected with the insulating material. If the cavity surface emissivities are lowered to 0.3, the improvement will be 72.73–78.33%. A model of thermal conduction accompanied with solidification and melting processes is developed and numerically analyzed by Chengbin Zhang et al [5] to investigate the thermal response of the brick wall filled with phase PCM.

The use of PCM in the brick walls is beneficial for the thermal insulation, temperature hysteresis and thermal comfort for occupancy. In addition, with the increasing filling amount of PCM, the fluctuation of indoor wall surface temperature is significantly smoothed. Correspondingly, the hysteresis in response to the outdoor temperature fluctuation is enhanced. An experimental research is presented by A.G. Entrop et al on a new use of Phase Change Materials (PCMs) in concrete floors, in which thermal energy provided by the sun is stored in a mix of concrete and PCMs. The application of PCMs in concrete floors resulted in a reduction of maximum floor temperatures up to 16 % and an increase of minimum temperatures up to 7%. The results show the relevance of an integral design in which the thermal resistance of the building shell, the sensible heat capacity of the building and the latent heat capacity of the PCMs are considered simultaneously.

The purpose of this study is to improve the thermal inertia of the outer wall of buildings located in hot arid areas. Two-dimensional numerical simulations were realized using the commercial software Fluent, to study the thermal behaviour of hollow clay bricks used in construction of habitats and institutions in Algeria. The improvement of the thermal inertia of the brick is realized by the insertion of a Phase Change Material (PCM) in some holes of the brick. An experimental model is made to see the thermal efficiency of the improved brick and on the other hand, to validate the numerical results. The Improved brick containing the PCM is optimized by choosing the best type, the best position and the optimal amount of PCM, to increase reduction of heat gain before it reaches the indoor space.

Chapter Two: the Theoretical Part and Literature Review

2. Building material

2.1. Introduction

Building material is material used for construction. Many naturally occurring substances, such as clay, rocks, sand, wood, and even twigs and leaves, have been used to construct buildings. Apart from naturally occurring materials, many man-made products are in use, some more and some less synthetic. The manufacturing of building materials is an established industry in many countries and the use of these materials is typically segmented into specific specialty trades, such as carpentry, insulation, plumbing, and roofing work. They provide the make-up of habitats and structures including homes. [6]

2.2. The total cost of building materials

In history, there are trends in building materials from being natural to becoming more man-made and composite; biodegradable to imperishable; indigenous (local) to being transported globally; repairable to disposable; chosen for increased levels of fire-safety, and improved seismic resistance. These trends tend to increase the initial and long term economic, ecological, energy, and social costs of building materials.

2.2.1.Economic costs

Initial economic cost of building materials is the purchase price. This is often what governs decision making about what materials to use. Sometimes people take into consideration the energy savings or durability of the materials and see the value of paying a higher initial cost in return for a lower lifetime cost. For example, an asphalt shingle roof costs less than a metal roof to install, but the metal roof will last longer so the lifetime cost is less per year. Some materials may require more care than others, maintaining costs specific to some materials may also influence the final decision. Risks when considering lifetime cost of a material is if the building is damaged such as by fire or wind, or if the material is not as durable as advertised. The cost of materials should be taken into consideration to bear the risk to buy combustive materials to enlarge the lifetime. It is said that, "if it must be done, it must be done well".

2.2.2.Ecological costs

Pollution costs can be macro and micro. The macro, environmental pollution of extraction industries building materials rely on such as mining, petroleum, and logging produce environmental damage at their source and in transportation of the raw materials, manufacturing, transportation of the products, retailing, and installation. An example of the micro aspect of pollution is the off-gassing of the building materials in the building or indoor air pollution. Red List building materials are materials found to be harmful. Also the carbon footprint, the total set of greenhouse gas emissions produced in the life of the material. A life-cycle analysis also includes the reuse, recycling, or disposal of construction waste. Two concepts in building which account for the ecological economics of building materials are green building and sustainable development.

2.2.3.Energy costs

the Initial energy costs include the amount of energy consumed to produce, deliver and install the material. The long term energy cost is the economic, ecological, and social costs of continuing to produce and deliver energy to the building for its use, maintenance, and eventual removal. The initial embodied energy of a structure is the energy consumed to extract, manufacture, deliver, install, the materials. The lifetime embodied energy continues to grow with the use, maintenance, and reuse/recycling/disposal of the building materials themselves and how the materials and design help minimize the life-time energy consumption of the structure.

2.2.4.Social costs

Social costs are injury and health of the people producing and transporting the materials and potential health problems of the building occupants if there are problems with the building biology. Globalization has had significant impacts on people both in terms of jobs, skills, and self-sufficiency are lost when manufacturing facilities are closed and the cultural aspects of where new facilities are opened. Aspects of fair trade and labor rights are social costs of global building material manufacturing.

2.3. Naturally occurring substances

2.3.1.Brush

A group of Mohaves in a brush hut Brush structures are built entirely from plant parts and were used in primitive cultures such as Native Americans and pygmy peoples in Africa[7] These are built mostly with branches, twigs and leaves, and bark, similar to a beaver's lodge. These were variously named wikiups, lean-tos, and so forth.

An extension on the brush building idea is the wattle and daub process in which clay soils or dung, usually cow, are used to fill in and cover a woven brush structure. This gives the structure more thermal mass and strength. Wattle and daub is one of the oldest building techniques. Many older timber frame buildings incorporate wattle and daub as non load bearing walls between the timber frames.

2.3.2.Ice and snow

Snow and occasionally ice, were used by the Inuit peoples for igloos and snow is used to build a shelter called a quinzhee. Ice has also been used for ice hotels as a tourist attraction in northern climates.[8]

2.3.3.Mud and clay

Sod buildings in Iceland Clay based buildings usually come in two distinct types. One being when the walls are made directly with the mud mixture, and the other being walls built by stacking air-dried building blocks called mud bricks. Other uses of clay in building is combined with straws to create light clay, wattle and daub, and mud plaster.

2.4 Structural clay blocks and bricks

2.4.1 Mud-brick and compressed earth block

Mud-bricks, also known by their Spanish name adobe are ancient building materials with evidence dating back thousands of years BC. Compressed earth blocks are a more modern type of brick used for building more frequently in industrialized society since the building blocks can be manufactured off site in a centralized location at a brickworks and transported to multiple building locations. These blocks can also be monetized more easily and sold.

Structural mud bricks are almost always made using clay, often clay soil and a binder are the only ingredients used, but other ingredients can include sand, lime, concrete, stone and other binders. The formed or compressed block is then air dried and can be laid dry or with a mortar or clay slip.

2.4.2. Wet-laid clay walls

Wet-laid, or damp, walls are made by using the mud or clay mixture directly without forming blocks and drying them first. The amount of and type of each material in the mixture used leads to different styles of buildings. The deciding factor is usually connected with the quality of the soil being used. Larger amounts of clay are usually employed in building with cob, while low-clay soil is usually associated with sod house or sod roof construction. The other main ingredients include more or less sand/gravel and straw/grasses. Rammed earth is both an old and newer take on creating walls, once made by compacting clay soils between planks by hand; nowadays forms and mechanical pneumatic compressors are used.[9]

Soil, and especially clay, provides good thermal mass; it is very good at keeping temperatures at a constant level. Homes built with earth tend to be naturally cool in the summer heat and warm in cold weather. Clay holds heat or cold, releasing it over a period of time like stone. Earthen walls change temperature slowly, so artificially raising or lowering the temperature can use more resources than in say a wood built house, but the heat/coolness stays longer.

People building with mostly dirt and clay, such as cob, sod, and adobe, created homes that have been built for centuries in western and northern Europe, Asia, as well as the rest of the world, and continue to be built, though on a smaller scale. Some of these buildings have remained habitable for hundreds of years.[10]

2.4.3.Sand

Sand is used with cement, and sometimes lime, to make mortar for masonry work and plaster. Sand is also used as a part of the concrete mix. An important low-cost building material in countries with high sand content soils is the Sandcrete block, which is weaker but cheaper than fired clay bricks.

2.4.4.Stone or rock

Rock structures have existed for as long as history can recall. It is the longest-lasting building material available, and is usually readily available. There are many types of rock, with differing attributes that make them better or worse for particular uses. Rock is a very dense material so it gives a lot of protection; its main drawback as a building material is its weight and the difficulty of working it. Its energy density is both an advantage and disadvantage. Stone is hard to warm without consuming considerable energy but, once warm, its thermal mass means that can retain heat for useful periods of time.[10]

Dry-stone walls and huts have been built for as long as humans have put one stone on top of another. Eventually, different forms of mortar were used to hold the stones together, cement being the most commonplace now.

The granite-strewn uplands of Dartmoor National Park, United Kingdom, for example, provided ample resources for early settlers. Circular huts were constructed from loose granite rocks throughout the Neolithic and early Bronze Age, and the remains of an estimated 5,000 can still be seen today. Granite continued to be used throughout the Medieval period (see Dartmoor longhouse) and into modern times. Slate is another stone type, commonly used as roofing material in the United Kingdom and other parts of the world where it is found.

Stone buildings can be seen in most major cities, and some civilizations built predominantly with stone, such as the Egyptian and Aztec pyramids and the structures of the Inca civilization.

2.4.5.Thatch

Thatch is one of the oldest of building materials known. "Thatch" is another word for "grass"; grass is a good insulator and easily harvested. Many African tribes have lived in homes made completely of grasses and sand year-round. In Europe, thatch roofs on homes were once prevalent but the material fell out of favor as industrialization and improved transport increased the availability of other materials. Today, though, the practice is undergoing a revival. In the Netherlands, for instance, many new buildings have thatched roofs with special ridge tiles on top.

2.4.6.Wood and timber

A wood-framed house under construction in Texas, United States, The Gliwice Radio Tower (the second tallest wooden structure in the world) in Poland (2012).

Wood has been used as a building material for thousands of years in its natural state. Today, engineered wood is becoming very common in industrialized countries.

Wood is a product of trees, and sometimes other fibrous plants, used for construction purposes when cut or pressed into lumber and timber, such as boards, planks and similar materials. It is a generic building material and is used in building just about any type of structure in most climates. Wood can be very flexible under loads, keeping strength while bending, and is incredibly strong when compressed vertically. There are many differing qualities to the different types of wood, even among same tree species. This means specific species are better suited for various uses than others. And growing conditions are important for deciding quality.

"Timber" is the term used for construction purposes except the term "lumber" is used in the United States. Raw wood (a log, trunk, bole) becomes timber when the wood has been "converted" (sawn, hewn, split) in the forms of minimally-processed logs stacked on top of each other, timber frame construction, and light-frame construction. The main problems with timber structures are fire risk and moisture-related problems.[citation needed]

In modern times softwood is used as a lower-value bulk material, whereas hardwood is usually used for finishings and furniture. Historically timber frame structures were built with oak in western Europe, recently douglas fir has become the most popular wood for most types of structural building.

Many families or communities, in rural areas, have a personal woodlot from which the family or community will grow and harvest trees to build with or sell. These lots are tended to like a garden. This was much more prevalent in pre-industrial times, when laws existed as to the amount of wood one could cut at any one time to ensure there would be a supply of timber for the future, but is still a viable form of agriculture.

2.5.Man-made substances

2.5.1.Fired bricks and clay blocks

A pile of fired bricks.

Clay blocks (sometimes called clay block brick) being laid with an adhesive rather than mortar

Bricks are made in a similar way to mud-bricks except without the fibrous binder such as straw and are fired ("burned" in a brick clamp or kiln) after they have air-dried to permanently harden them. Kiln fired clay bricks are a ceramic material. Fired bricks can be solid or have hollow cavities to aid in drying and make them lighter and easier to transport. The individual bricks are placed upon each other in courses using mortar. Successive courses being used to build up walls, arches, and other architectural elements. Fired brick walls are usually substantially thinner than cob/adobe while keeping the same vertical strength. They require more energy to create but are easier to transport and store, and are lighter than stone blocks. Romans extensively used fired brick of a shape and type now called Roman bricks.[11] Building with brick gained much popularity in the mid-18th century and 19th centuries. This was due to lower costs with increases in brick manufacturing and fire-safety in the ever crowding cities.

The cinder block supplemented or replaced fired bricks in the late 20th century often being used for the inner parts of masonry walls and by themselves. Structural clay tiles (clay blocks) are clay or terracotta and typically are perforated with holes.

2.5.2.Cement composites

Cement bonded composites are made of hydrated cement paste that binds wood, particles, or fibers to make pre-cast building components. Various fiberous materials, including paper, fiberglass, and carbon-fiber have been used as binders.

Wood and natural fibers are composed of various soluble organic compounds like carbohydrates, glycosides and phenolics. These compounds are known to retard cement setting. Therefore, before using a wood in making cement bonded composites, its compatibility with cement is assessed.

Wood-cement compatibility is the ratio of a parameter related to the property of a wood-cement composite to that of a neat cement paste. The compatibility is often expressed as a percentage value. To determine wood-cement compatibility, methods based on different properties are used, such as, hydration characteristics, strength, interfacial bond and morphology. Various methods are used by researchers such as the measurement of hydration characteristics of a cement-aggregate mix; the comparison of the mechanical properties of cement-aggregate mixes[12] and the visual assessment of microstructural properties of the wood-cement mixes. It has been found that the hydration test by measuring the change in hydration temperature with time is the most convenient method. Recently, Karade et al. have reviewed these methods of compatibility assessment and suggested a method based on the ‘maturity concept’ i.e. taking in consideration both time and temperature of cement hydration reaction.

Bricks were laid in lime mortar from the time of the Romans until supplanted by Portland cement mortar in the early 20th century. Cement blocks also sometimes are filled with grout or covered with a parge coat.

2.5.3.Concrete

Concrete is a composite building material made from the combination of aggregate and a binder such as cement. The most common form of concrete is Portland cement concrete, which consists of mineral aggregate (generally gravel and sand), portland cement and water. After mixing, the cement hydrates and eventually hardens into a stone-like material. When used in the generic sense, this is the material referred to by the term "concrete".

For a concrete construction of any size, as concrete has a rather low tensile strength, it is generally strengthened using steel rods or bars (known as rebars). This strengthened concrete is then referred to as reinforced concrete. In order to minimise any air bubbles, that would weaken the structure, a vibrator is used to eliminate any air that has been entrained when the liquid concrete mix is poured around the ironwork. Concrete has been the predominant building material in the modern age due to its longevity, formability, and ease of transport. Recent advancements, such as insulating concrete forms, combine the concrete forming and other construction steps (installation of insulation). All materials must be taken in required proportions as described in standards

2.5.4.Fabric

The tent is the home of choice among nomadic groups all over the world. Two well-known types include the conical teepee and the circular yurt. The tent has been revived as a major construction technique with the development of tensile architecture and synthetic fabrics. Modern buildings can be made of flexible material such as fabric membranes, and supported by a system of steel cables, rigid or internal, or by air pressure.

2.5.5.Foam

Recently, synthetic polystyrene or polyurethane foam has been used in combination with structural materials, such as concrete. It is lightweight, easily shaped, and an excellent insulator. Foam is usually used as part of a structural insulated panel, wherein the foam is sandwiched between wood or cement or insulating concrete forms.

2.5.6.Glass

Glassmaking is considered an art form as well as an industrial process or material.

Clear windows have been used since the invention of glass to cover small openings in a building. Glass panes provided humans with the ability to both let light into rooms while at the same time keeping inclement weather outside.

Glass is generally made from mixtures of sand and silicates, in a very hot fire stove called a kiln, and is very brittle. Additives are often included the mixture used to produce glass with shades of colors or various characteristics (such as bulletproof glass or lightbulbs).

The use of glass in architectural buildings has become very popular in the modern culture. Glass "curtain walls" can be used to cover the entire facade of a building, or it can be used to span over a wide roof structure in a "space frame". These uses though require some sort of frame to hold sections of glass together, as glass by itself is too brittle and would require an overly large kiln to be used to span such large areas by itself.

Glass bricks were invented in the early 20th century.

2.5.7.Gypsum concrete

Gypsum concrete is a mixture of gypsum plaster and fibreglass rovings. Although plaster and fibres fibrous plaster have been used for many years, especially for ceilings, it was not until the early 1990s that serious studies of the strength and qualities of a walling system Rapidwall, using a mixture of gypsum plaster and 300mm plus fibreglass rovings, were investigated. With an abundance of gypsum (naturally occurring and by-product chemical FGD and phospho gypsums) available worldwide, Gypsum concrete-based building products, which are fully recyclable, offer significant environmental benefits.

2.5.8.Metal

Metal is used as structural framework for larger buildings such as skyscrapers, or as an external surface covering. There are many types of metals used for building. Metal figures quite prominently in prefabricated structures such as the Quonset hut, and can be seen used in most cosmopolitan cities. It requires a great deal of human labor to produce metal, especially in the large amounts needed for the building industries. Corrosion is metal's prime enemy when it comes to longevity.

- Steel is a metal alloy whose major component is iron, and is the usual choice for metal structural building materials. It is strong, flexible, and if refined well and/or treated lasts a long time.
- The lower density and better corrosion resistance of aluminium alloys and tin sometimes overcome their greater cost.
- Copper is a valued building material because of its advantageous properties (see: Copper in architecture). These include corrosion resistance, durability, low thermal movement, light weight, radio frequency shielding, lightning protection, sustainability, recyclability, and a wide range of finishes. Copper is incorporated into roofing, flashing, gutters, downspouts, domes, spires, vaults, wall cladding, building expansion joints, and indoor design elements.
- Other metals used include chrome, gold, silver, and titanium. Titanium can be used for structural purposes, but it is much more expensive than steel. Chrome, gold, and silver are used as decoration, because these materials are expensive and lack structural qualities such as tensile strength or hardness.

2.5.9.Plastics

The term plastics covers a range of synthetic or semi-synthetic organic condensation or polymerization products that can be molded or extruded into objects, films, or fibers. Their name is derived from the fact that in their semi-liquid state they are malleable, or have the property of plasticity. Plastics vary immensely in heat tolerance, hardness, and resiliency. Combined with this adaptability, the general uniformity of composition and lightness of plastics ensures their use in almost all industrial applications today. High performance plastics such as ETFE have become an ideal building material due to its high abrasion resistance and chemical inertness. Notable buildings that feature it include: the Beijing National Aquatics Center and the Eden Project biomes.[13]

2.5.10.Papers and membranes

Building papers and membranes are used for many reasons in construction. One of the oldest building papers is red rosin paper which was known to be in use before 1850 and was used as an underlayment in exterior walls, roofs, and floors and for protecting a jobsite during construction. Tar paper was invented late in the 19th century and was used for similar purposes as rosin paper and for gravel roofs. Tar paper has largely fallen out of use supplanted by asphalt felt paper. Felt paper has been supplanted in some uses by synthetic underlayment's, particularly in roofing by synthetic underlayments and siding by house wraps. There are a wide variety of damp proofing and waterproofing membranes used for roofing, basement waterproofing, and geomembranes.

2.5.11.Ceramics

Fired clay bricks have been used since the time of the Romans. Special tiles are used for roofing, siding, flooring, ceilings, pipes, flue liners, and more.

2.6.Living building materials

A relatively new category of building materials, living building materials are materials that are either composed of, or created by a living organism; or materials that behave in a manner that's reminiscent of such. Potential use cases include self-healing materials, and materials that replicate (reproduce) rather than be manufactured.

2.6.1.Building products

In the market place, the term "building products" often refers to ready-made particles or sections made from various materials, that are fitted in architectural hardware and decorative hardware parts of a building. The list of building products excludes the building materials used to construct the building architecture and supporting fixtures, like windows, doors, cabinets, millwork components, etc. Building products, rather, support and make building materials work in a modular fashion.

"Building products" may also refer to items used to put such hardware together, such as caulking, glues, paint, and anything else bought for the purpose of constructing a building.

2.7.Research and development

To facilitate and optimize the use of new materials and up-to-date technologies, ongoing research is being undertaken to improve efficiency, productivity and competitiveness in world markets.

Material research and development may be commercial, academical or both, and can be conducted at any scale. An example of a building material prototyping facility is the open source Forty Walls House in Australia, where up to 40 new sustainable materials are being rapidly prototyped and tested simultaneously in a building that is permanently occupied and monitored.[14]

Rapid prototyping allows researchers to develop and test materials quickly, making adjustments and solving issues during the process. Rather than developing materials theoretically and then testing them, only to discover fundamental flaws, rapid prototypes allow for comparatively quick development and testing, shortening the time to market for a new materials to a matter of months, rather than years.[15]

2.8.Brick

A brick is a type of block used to build walls, pavements and other elements in masonry construction. Properly, the term brick denotes a block composed of dried clay, but is now also used informally to denote other chemically cured construction blocks. Bricks can be joined using mortar, adhesives or by interlocking them.[16] Bricks are usually produced at brickworks in numerous classes, types, materials, and sizes which vary with region and time period, and are produced in bulk quantities. Block is a similar term referring to a rectangular building unit composed of similar materials, but is usually larger than a brick. Lightweight bricks (also called lightweight blocks) are made from expanded clay aggregate. Fired bricks are one of the longest-lasting and strongest building materials, sometimes referred to as artificial stone, and have been used since circa 4000 BC. Air-dried bricks, also known as mud-bricks, have a history older than fired bricks, and have an additional ingredient of a mechanical binder such as straw. Bricks are laid in courses and numerous patterns known as bonds, collectively known as brickwork, and may be laid in various kinds of mortar to hold the bricks together to make a durable structure.

2.8.1. History

2.8.1.1. Middle East and South Asia

The ancient Jetavanaramaya stupa of Anuradhapura in Sri Lanka is one of the largest brick structures in the world. The earliest bricks were dried mud-bricks, meaning that they were formed from clay-bearing earth or mud and dried (usually in the sun) until they were strong enough for use. The oldest discovered bricks, originally made from shaped mud and dating before 7500 BC, were found at Tell Aswad, in the upper Tigris region and in southeast Anatolia close to Diyarbakir. Mud-brick construction was used at Çatalhöyük, from c. 7,400 BC. Mud-brick structures, dating to c. 7,200 BC have been located in Jericho, Jordan Valley. These structures were made up of the first bricks with dimension 400x150x100 mm. Between 5000 and 4500 BC, Mesopotamia had discovered fired brick. The standard brick sizes in Mesopotamia followed a general rule: the width of the dried or burned brick would be twice its thickness, and its length would be double its width. The South Asian inhabitants of Mehrgarh also constructed, air-dried mud-brick structures, between 7000 and 3300 BC. and later the ancient Indus Valley cities of Mohenjo-daro, Harappa, and Mehrgarh.[17] Ceramic, or fired brick was used as early as 3000 BC in early Indus Valley cities like Kalibangan.[18] In the middle of the third millennium BC, there was a rise in monumental baked brick

architecture in Indus cities. Examples included the Great Bath at Mohenjo-daro, the fire altars of Kaalibangan, and the granary of Harappa. There was a uniformity to the brick sizes throughout the Indus Valley region, conforming to the 1:2:4, thickness, width, and length ratio. As the Indus civilization began its decline at the start of the second millennium BC, Harappans migrated east, spreading their knowledge of brickmaking technology. This led to the rise of cities like Pataliputra, Kausambi, and Ujjain, where there was an enormous demand for kiln-made bricks.[19] By 604 BC, bricks were the construction materials for architectural wonders such as the Hanging Gardens of Babylon, where glazed fired bricks were put into practice.

2.8.1.2.China

The earliest fired bricks appeared in Neolithic China around 4400 BC at Chengtoushan, a walled settlement of the Daxi culture. These bricks were made of red clay, fired on all sides to above 600 °C, and used as flooring for houses. By the Qujialing period (3300 BC), fired bricks were being used to pave roads and as building foundations at Chengtoushan. According to Lukas Nickel, the use of ceramic pieces for protecting and decorating floors and walls dates back at various cultural sites to 3000-2000 BC and perhaps even before, but these elements should be rather qualified as tiles. For the longest time builders relied on wood, mud and rammed earth, while fired brick and mud-brick played no structural role in architecture. Proper brick construction, for erecting walls and vaults, finally emerges in the third century BC, when baked bricks of regular shape began to be employed for vaulting underground tombs. Hollow brick tomb chambers rose in popularity as builders were forced to adapt due to a lack of readily available wood or stone.[20] The oldest extant brick building above ground is possibly Songyue Pagoda, dated to 523 AD. By the end of the third century BCE in China, both hollow and small bricks were available for use in building walls and ceilings. Small fired bricks were first mass-produced during the construction of the tomb of China's first Emperor, Qin Shi Huangdi. The floors of the three pits of the terracotta army were paved with an estimated 230,000 small bricks, with the majority measuring 28x14x7 cm, following a 4:2:1 ratio. Up until the Middle Ages, buildings in Central Asia were typically built with unbaked bricks. It was only starting in the ninth century CE when buildings were entirely constructed using fired bricks. The carpenter's manual Yingzao Fashi, published in 1103 at the time of the Song dynasty described the brick making process and glazing techniques then in use. Using the 17th-century encyclopaedic text Tiangong Kaiwu, historian Timothy Brook outlined the brick production process of Ming Dynasty China: ...the kilnmaster had to make sure that the temperature inside the kiln stayed at a

level that caused the clay to shimmer with the colour of molten gold or silver. He also had to know when to quench the kiln with water so as to produce the surface glaze. To anonymous labourers fell the less skilled stages of brick production: mixing clay and water, driving oxen over the mixture to trample it into a thick paste, scooping the paste into standardised wooden frames (to produce a brick roughly 42 cm long, 20 cm wide, and 10 cm thick), smoothing the surfaces with a wire-strung bow, removing them from the frames, printing the fronts and backs with stamps that indicated where the bricks came from and who made them, loading the kilns with fuel (likelier wood than coal), stacking the bricks in the kiln, removing them to cool while the kilns were still hot, and bundling them into pallets for transportation. It was hot, filthy work.

2.8.1.3.Europe

1.Roman brick

Early civilisations around the Mediterranean, including the Ancient Greeks and Romans, adopted the use of fired bricks. By the early first century CE, standardised fired bricks were being heavily produced in Rome. The Roman legions operated mobile kilns, and built large brick structures throughout the Roman Empire, stamping the bricks with the seal of the legion.[21] The Romans used brick for walls, arches, forts, aqueducts, etc. Notable mentions of Roman brick structures are the Herculaneum gate of Pompeii and the baths of Caracalla. During the Early Middle Ages the use of bricks in construction became popular in Northern Europe, after being introduced there from Northwestern Italy. An independent style of brick architecture, known as brick Gothic (similar to Gothic architecture) flourished in places that lacked indigenous sources of rocks. Examples of this architectural style can be found in modern-day Denmark, Germany, Poland, and Kaliningrad (former East Prussia). This style evolved into the Brick Renaissance as the stylistic changes associated with the Italian Renaissance spread to northern Europe, leading to the adoption of Renaissance elements into brick building. Identifiable attributes included a low-pitched hipped or flat roof, symmetrical facade, round arch entrances and windows, columns and pilasters, and more.[22] A clear distinction between the two styles only developed at the transition to Baroque architecture. In Lübeck, for example, Brick Renaissance is clearly recognisable in buildings equipped with terracotta reliefs by the artist Statius von Düren, who was also active at Schwerin (Schwerin Castle) and Wismar (Fürstenhof).[citation needed] Long-distance bulk

transport of bricks and other construction equipment remained prohibitively expensive until the development of modern transportation infrastructure, with the construction of canal, roads, and railway.

2.Industrial era

Production of bricks increased massively with the onset of the Industrial Revolution and the rise in factory building in England. For reasons of speed and economy, bricks were increasingly preferred as building material to stone, even in areas where the stone was readily available. It was at this time in London that bright red brick was chosen for construction to make the buildings more visible in the heavy fog and to help prevent traffic accidents. The transition from the traditional method of production known as hand-moulding to a mechanised form of mass-production slowly took place during the first half of the nineteenth century. Possibly the first successful brick-making machine was patented by Henry Clayton, employed at the Atlas Works in Middlesex, England, in 1855, and was capable of producing up to 25,000 bricks daily with minimal supervision. His mechanical apparatus soon achieved widespread attention after it was adopted for use by the South Eastern Railway Company for brick-making at their factory near Folkestone.[23] The Bradley & Craven Ltd 'Stiff-Plastic Brickmaking Machine' was patented in 1853, apparently predating Clayton. Bradley & Craven went on to be a dominant manufacturer of brickmaking machinery. Predating both Clayton and Bradley & Craven Ltd. however was the brick making machine patented by Richard A. Ver Valen of Haverstraw, New York, in 1852.[28] At the end of the 19th century, the Hudson River region of New York State would become the world's largest brick manufacturing region, with 130 brickyards lining the shores of the Hudson River from Mechanicsville to Haverstraw and employing 8,000 people. At its peak, about 1 billion bricks were produced a year, with many being sent to New York City for use in its construction industry.[24] The demand for high office building construction at the turn of the 20th century led to a much greater use of cast and wrought iron, and later, steel and concrete. The use of brick for skyscraper construction severely limited the size of the building – the Monadnock Building, built in 1896 in Chicago, required exceptionally thick walls to maintain the structural integrity of its 17 storeys.[25] Following pioneering work in the 1950s at the Swiss Federal Institute of Technology and the Building Research Establishment in Watford, UK, the use of improved masonry for the construction of tall structures up to 18 storeys high was made viable. However, the use of brick has largely

remained restricted to small to medium-sized buildings, as steel and concrete remain superior materials for high-rise construction. Bricks are often made of shale because it easily splits into thin layers.[citation needed]

2.8.2. Methods of manufacture

Four basic types of brick are un-fired, fired, chemically set bricks, and compressed earth blocks. Each type is manufactured differently for various purposes

2.8.2.1. Mud-brick

Unfired bricks, also known as mud-bricks, are made from a mixture of silt, clay, sand and other earth materials like gravel and stone, combined with tempers and binding agents such as chopped straw, grasses, tree bark, or dung. Since these bricks are made up of natural materials and only require heat from the Sun to bake, mud-bricks have a relatively low embodied energy and carbon footprint. The ingredients are first harvested and added together, with clay content ranging from 30% to 70%. The mixture is broken up with hoes or adzes, and stirred with water to form a homogenous blend. Next, the tempers and binding agents are added in a ratio, roughly one part straw to five parts earth to reduce weight and reinforce the brick by helping reduce shrinkage.[26] However, additional clay could be added to reduce the need for straw, which would prevent the likelihood of insects deteriorating the organic material of the bricks, subsequently weakening the structure. These ingredients are thoroughly mixed together by hand or by treading and are then left to ferment for about a day. The mix is then kneaded with water and molded into rectangular prisms of a desired size. Bricks are lined up and left to sundry for three days on both sides. After the six days, the bricks continue drying until required for use. Typically, longer drying times are preferred, but the average is eight to nine days spanning from initial stages to its application in structures. Unfired bricks could be made in the spring months and left to dry over the summer for use in the fall. Mud-bricks are commonly employed in arid environments to allow for adequate air drying.

2.8.2.2.Fired brick

Fired bricks are burned in a kiln which makes them durable. Modern, fired, clay bricks are formed in one of three processes – soft mud, dry press, or extruded. Depending on the country, either the extruded or soft mud method is the most common, since they are the most economical.

Clay and shale are the raw ingredients in the recipe for a fired brick. They are the product of thousands of years of decomposition and erosion of rocks, such as pegmatite and granite, leading to a material that has properties of being highly chemically stable and inert. Within the clays and shales are the materials of aluminosilicate (pure clay), free silica (quartz), and decomposed rock.[27]

One proposed optimal mix is:

Silica (sand) – 50% to 60% by weight

Alumina (clay) – 20% to 30% by weight

Lime – 2 to 5% by weight

Iron oxide – ≤ 7% by weight

Magnesia – less than 1% by weight

2.8.2.3.Shaping methods

Three main methods are used for shaping the raw materials into bricks to be fired:

Molded bricks – These bricks start with raw clay, preferably in a mix with 25–30% sand to reduce shrinkage. The clay is first ground and mixed with water to the desired consistency. The clay is then pressed into steel moulds with a hydraulic press. The shaped clay is then fired ("burned") at 900–1,000 °C (1,650–1,830 °F) to achieve strength.

Dry-pressed bricks – The dry-press method is similar to the soft-mud moulded method, but starts with a much thicker clay mix, so it forms more accurate, sharper-edged bricks. The greater force in pressing and the longer burn make this method more expensive.

Extruded bricks – For extruded bricks the clay is mixed with 10–15% water (stiff extrusion) or 20–25% water (soft extrusion) in a pugmill. This mixture is forced through a die to create a long cable of material of the desired width and depth. This mass is then cut into bricks of the desired length by a wall of wires. Most structural bricks are made by this method as it produces hard, dense bricks, and suitable dies can produce perforations as well. The introduction of such holes reduces the volume of clay needed, and hence the cost. Hollow bricks are lighter and easier to handle, and have different thermal properties from solid bricks. The cut bricks are hardened by drying for 20 to 40 hours at 50 to 150 °C (120 to 300 °F) before being fired. The heat for drying is often waste heat from the kiln.

2.8.2.4.Kilns

In many modern brickworks, bricks are usually fired in a continuously fired tunnel kiln, in which the bricks are fired as they move slowly through the kiln on conveyors, rails, or kiln cars, which achieves a more consistent brick product. The bricks often have lime, ash, and organic matter added, which accelerates the burning process.

The other major kiln type is the Bull's Trench Kiln (BTK), based on a design developed by British engineer W. Bull in the late 19th century.

An oval or circular trench is dug, 6–9 metres (20–30 ft) wide, 2–2.5 metres (6 ft 7 in – 8 ft 2 in) deep, and 100–150 metres (330–490 ft) in circumference. A tall exhaust chimney is constructed in the centre. Half or more of the trench is filled with "green" (unfired) bricks which are stacked in an open lattice pattern to allow airflow. The lattice is capped with a roofing layer of finished brick.

In operation, new green bricks, along with roofing bricks, are stacked at one end of the brick pile. Historically, a stack of unfired bricks covered for protection from the weather was called a "hack". Cooled finished bricks are removed from the other end for transport to their destinations. In the middle, the brick workers create a firing zone by dropping fuel (coal, wood, oil, debris, etc.) through access holes in the roof above the trench. The constant source of fuel maybe grown on the woodlots.

The advantage of the BTK design is a much greater energy efficiency compared with clamp or scove kilns. Sheet metal or boards are used to route the airflow through the brick lattice so that fresh air flows first through the recently burned bricks, heating the air, then through the active burning zone. The air continues through the green brick zone (pre-heating and drying the bricks), and finally out the chimney, where the rising gases create suction that pulls air through the system. The reuse of heated air yields savings in fuel cost.

As with the rail process, the BTK process is continuous. A half-dozen labourers working around the clock can fire approximately 15,000–25,000 bricks a day. Unlike the rail process, in the BTK process the bricks do not move. Instead, the locations at which the bricks are loaded, fired, and unloaded gradually rotate through the trench.[28]

2.8.2.5.Influences on colour

The colour of fired clay bricks is influenced by the chemical and mineral content of the raw materials, the firing temperature, and the atmosphere in the kiln. For example, pink bricks are the result of a high iron content, white or yellow bricks have a higher lime content.[29] Most bricks burn to various red hues; as the temperature is increased the colour moves through dark red, purple, and then to brown or grey at around 1,300 °C (2,370 °F). The names of bricks may reflect their origin and colour, such as London stock brick and Cambridgeshire White. Brick tinting may be performed to change the colour of bricks to blend-in areas of brickwork with the surrounding masonry.

An impervious and ornamental surface may be laid on brick either by salt glazing, in which salt is added during the burning process, or by the use of a slip, which is a glaze material into which the bricks are dipped. Subsequent reheating in the kiln fuses the slip into a glazed surface integral with the brick base.

2.8.2.6.Chemically set bricks

Chemically set bricks are not fired but may have the curing process accelerated by the application of heat and pressure in an autoclave. Calcium-silicate bricks are also called sandlime or flintlime bricks, depending on their ingredients. Rather than being made with clay they are made with lime binding the silicate material. The raw materials for calcium-silicate bricks include lime mixed in a proportion of about 1 to 10 with sand, quartz, crushed flint, or crushed siliceous rock together with mineral colourants.

The materials are mixed and left until the lime is completely hydrated; the mixture is then pressed into moulds and cured in an autoclave for three to fourteen hours to speed the chemical hardening.[30] The finished bricks are very accurate and uniform, although the sharp arrises need careful handling to avoid damage to brick and bricklayer. The bricks can be made in a variety of colours; white, black, buff, and grey-blues are common, and pastel shades can be achieved. This type of brick is common in Sweden as well as Russia and other post-Soviet countries, especially in houses built or renovated in the 1970s. A version known as fly ash bricks, manufactured using fly ash, lime, and gypsum (known as the FaL-G process) are common in South Asia. Calcium-silicate bricks are also manufactured in Canada and the United States, and meet the criteria set forth in ASTM C73 – 10 Standard Specification for Calcium Silicate Brick (Sand-Lime Brick).

2.8.3.Types

This wall in Beacon Hill, Boston, shows different types of brickwork and stone foundations

There are thousands of types of bricks that are named for their use, size, forming method, origin, quality, texture, and/or materials.

Categorized by manufacture method:

- Extruded – made by being forced through an opening in a steel die, with a very consistent size and shape.
- Wire-cut – cut to size after extrusion with a tensioned wire which may leave drag marks
- Moulded – shaped in moulds rather than being extruded
- Machine-moulded – clay is forced into moulds using pressure
- Handmade – clay is forced into moulds by a person
- Dry-pressed – similar to soft mud method, but starts with a much thicker clay mix and is compressed with great force.
- Categorized by use:
- Common or building – A brick not intended to be visible, used for internal structure
- Face – A brick used on exterior surfaces to present a clean appearance
- Hollow – not solid, the holes are less than 25% of the brick volume
- Perforated – holes greater than 25% of the brick volume
- Keyed – indentations in at least one face and end to be used with rendering and plastering
- Paving – brick intended to be in ground contact as a walkway or roadway
- Thin – brick with normal height and length but thin width to be used as a veneer
- Specialized use bricks:
- Chemically resistant – bricks made with resistance to chemical reactions
- Acid brick – acid resistant bricks

- Engineering – a type of hard, dense, brick used where strength, low water porosity or acid (flue gas) resistance are needed. Further classified as type A and type B based on their compressive strength
- Accrington – a type of engineering brick from England
- Fire or refractory – highly heat-resistant bricks
- Clinker – a vitrified brick
- Ceramic glazed – fire bricks with a decorative glazing
- Bricks named for place of origin:
- Cream City brick – a light yellow brick made in Milwaukee, Wisconsin
- Dutch brick – a hard light coloured brick originally from the Netherlands
- Fareham red brick – a type of construction brick
- London stock brick – type of handmade brick which was used for the majority of building work in London and South East England until the growth in the use of machine-made bricks
- Nanak Shahi bricks – a type of decorative brick in India
- Roman brick – a long, flat brick typically used by the Romans
- Staffordshire blue brick – a type of construction brick from England

2.8.4.Optimal dimensions, characteristics, and strength

For efficient handling and laying, bricks must be small enough and light enough to be picked up by the bricklayer using one hand (leaving the other hand free for the trowel). Bricks are usually laid flat, and as a result, the effective limit on the width of a brick is set by the distance which can conveniently be spanned between the thumb and fingers of one hand, normally about 100 mm (4 in). In most cases, the length of a brick is twice its width plus the width of a mortar joint, about 200 mm (8 in) or slightly more. This allows bricks to be laid bonded in a structure which increases stability and strength (for an example, see the illustration of bricks laid in English bond, at the head of this article). The wall is built using alternating courses of stretchers, bricks laid longways, and headers, bricks laid crossways. The headers tie the wall together over its width. In fact, this wall is built in a variation of English bond called English cross bond where the successive layers of stretchers are displaced horizontally from each other by half a brick length. In true English bond, the perpendicular lines of the stretcher courses are in line with each other.

A bigger brick makes for a thicker (and thus more insulating) wall. Historically, this meant that bigger bricks were necessary in colder climates (see for instance the slightly larger size of the Russian brick in table below), while a smaller brick was adequate, and more economical, in warmer regions. A notable illustration of this correlation is the Green Gate in Gdansk; built in 1571 of imported Dutch brick, too small for the colder climate of

Gdansk, it was notorious for being a chilly and drafty residence. Nowadays this is no longer an issue, as modern walls typically incorporate specialised insulation materials.

The correct brick for a job can be selected from a choice of colour, surface texture, density, weight, absorption, and pore structure, thermal characteristics, thermal and moisture movement, and fire resistance.

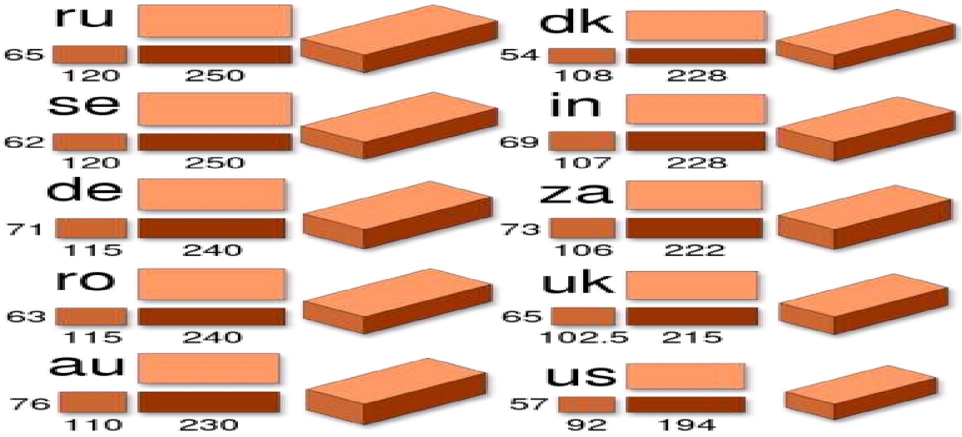


Figure.1.Comparison of typical brick sizes of assorted countries with isometric projections and dimensions in millimetres

2.8.5. Uses

Bricks are a versatile building material, able to participate in a wide variety of applications, including:

- Structural walls, exterior and interior walls
- Bearing and non-bearing sound proof partitions
- The fireproofing of structural-steel members in the form of firewalls, party walls, enclosures and fire towers
- Foundations for stucco
- Chimneys and fireplaces
- Porches and terraces
- Outdoor steps, brick walks and paved floors
- Swimming pools

In the United States, bricks have been used for both buildings and pavement. Examples of brick use in buildings can be seen in colonial era buildings and other notable structures around the country. Bricks have been used in paving roads and sidewalks especially during the late 19th century and early 20th century. The introduction of asphalt and concrete reduced the use of brick for paving, but they are still sometimes installed as a method of traffic calming or as a decorative surface in pedestrian precincts. For example, in the early 1900s, most of the streets in the city of Grand Rapids, Michigan, were paved with bricks. Today, there are only about 20 blocks of brick-paved streets remaining (totaling less than 0.5 percent of all the streets in the city limits).[31] Much like in Grand Rapids, municipalities across the United States began replacing brick streets with inexpensive asphalt concrete by the mid-20th century.[32]

In Northwest Europe, bricks have been used in construction for centuries. Until recently, almost all houses were built almost entirely from bricks. Although many houses are now built using a mixture of concrete blocks and other materials, many houses are skinned with a layer of bricks on the outside for aesthetic appeal.

Bricks in the metallurgy and glass industries are often used for lining furnaces, in particular refractory bricks such as silica, magnesia, chamotte and neutral (chromomagnesite) refractory bricks. This type of brick must have good thermal shock resistance, refractoriness under load, high melting point, and satisfactory porosity. There is a large refractory brick industry, especially in the United Kingdom, Japan, the United States, Belgium and the Netherlands.

Engineering bricks are used where strength, low water porosity or acid (flue gas) resistance are needed. In the UK a red brick university is one founded in the late 19th or early 20th century. The term is used to refer to such institutions collectively to distinguish them from the older Oxbridge institutions, and refers to the use of bricks, as opposed to stone, in their buildings. Colombian architect Rogelio Salmona was noted for his extensive use of red bricks in his buildings and for using natural shapes like spirals, radial geometry and curves in his designs. [33]

Chapter Three: Experimental work

3.1. The devices that used with the manufacturing method

Figure.1.The hopper : It is a large basin where its work is to divide the dirt on the conveyor belt.

Figure.2.Conveyor belt. It is a belt that pulls the dirt from the hopper and transfers it to the kneader

Figure.3.Ground kneader. It is a basin containing parts inside it for mixing the dirt coming from the hopper, where the clay is mixed with water to complete the kneading process to turn it into solid clay .

Figure.4.The upper kneader :- It is a kneader similar to the ground kneader, except that it contains a pressing chamber, the purpose of which is to empty the clay from the air.

Figure.5.The machine that cuts the clay and sends it to the brick making mold.

3.2. Tests of Bricks

3.2.1. Test the dimensions of the brick

3.2.1.1.Purpose of the test: - Determine the dimensions of the bricks

3.2.1.2.Device and Apparatus

Steel tape measure

Procedure In this Test, the Iraqi Standard Specifications No. 24 of 1988 (IQS 24-1988) were adopted.

The average dimensions of (24) bricks are calculated by paving the bricks closely along a straight line on a flat surface as shown in Figure No. (1). The length, width and thickness are measured using a ruler or tape, and the bumps and suspended sand grains must be removed before paving the bricks. Steel, and if it is not possible to specify (24) bricks, then the determination of the dimensions can be carried out on two groups of (12) bricks or three groups of (8) bricks, so that each group is measured separately to the nearest 0.3 cm, and the total represents the dimensions (24) bricks. The arithmetic average of the dimensions is also (24) Bricks that are representative of the dimensions of the examined bricks.

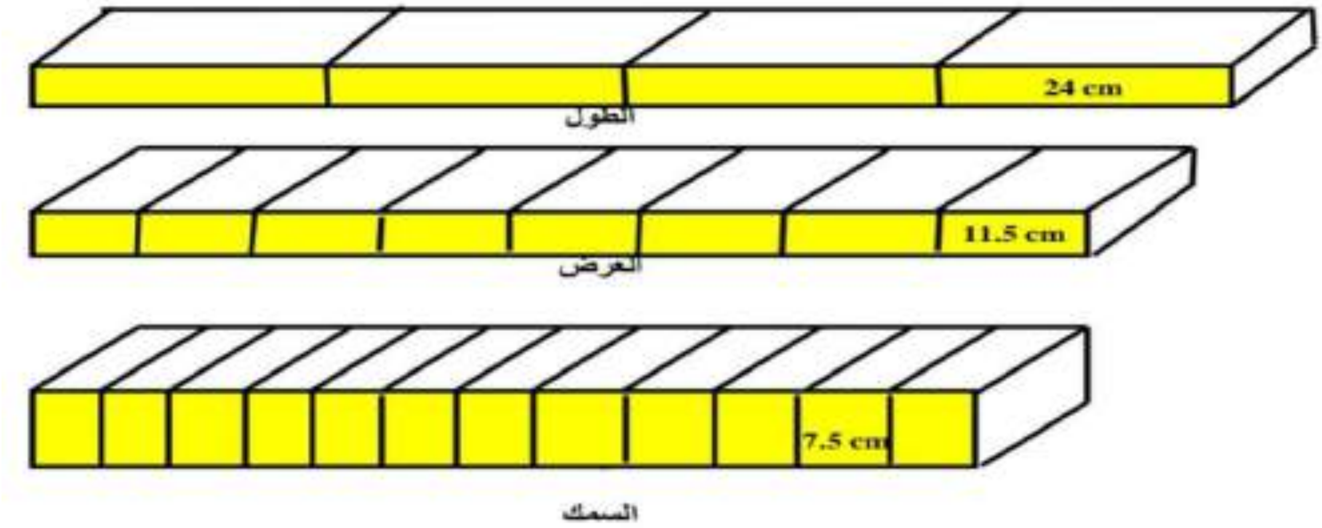


Figure (1) The different situations for determining the sizes

The Iraqi specifications No. 25 of 1988 specified the dimensions of the bricks (7.5 * 11.5 * 24) cm for all types of bricks, and the amount of tolerance for the dimensions is ± 3%ess for the length and width and ± 4% for the thicken.

3.2.2.Test Strength Compressive

3.2.2.1.The purpose of the test

The aim of this test is to determine the compressive strength of the bricks in order to know the extent to which the bricks can bear the highest stress that they can bear before breaking, which allows us to determine the best type of bricks to be used in the construction of engineering facilities The test is carried out on (10) blocks and the average is taken **.**

3.2.2.2.Device and apparatus used

- A pressure check device (Fig. 2).
- Sheets of plywood**.**
- Basins of water.

Figure (2) Compression device for testing bricks .

3.2.2.3.Test method

In this examination, the Iraqi Standard Specifications No. 24 of 1988 (IQS 24-1988) were approved.

1- Ten bricks are taken and each brick is numbered with a specific number**.**
2- The model is immersed in water at room temperature for at least 24 hours.
3- The model is removed from the water and dried with a cloth, then placed between two sheets of plywood with a thickness of 2 mm and placed between the two plates of the compression tester so that the axis of the model applies to the center of the plate of the compression device. The two horizontal brick surfaces when constructing the wall are the loading surfaces (per minute until the fraction. Then it is extracted.
4- 4- The test sample bears a uniform axial pressure of (3.5 Nt/mm) compressive strength for each brick of the following relationship:

Compressive strength = fracture load / surface area

By their number, the pressure rate is taken for the ten blocks, and the blocks are classified according to the “three blocks” as determined by the Iraqi specifications M.P.S. 25 of 1988 and as shown in Table No. (1) . When calculating the area for bricks.

3.2.3. Absorption test

The presence of pores in the structure of the brick leads to an increase in the brick's absorption of water, which leads to:

1-whenever the water absorption of the brick increases, this leads to a decrease in the pressure-bearing strength of the brick

2- This water may contain salts that lead to flowering**.**

3-It also negatively affects the binder through its absorption of the water of the binder, and for this reason the bricks are sprayed with water before construction.

4-Freezing of water inside the pores of the brick leads to an increase in its volume and thus causes damage to the brick and the bonding material, so the absorption of water has a relationship to the durability of the brick and its durability.

5-Increased water absorption leads to damage to the finish layers and pigments.

3.2.3.1.The reason for the presence of pores in the bricks is due to:

- The amount of compression during manufacturing**.**
- The percentage of water when making bricks**.**
- Burning temperature**.**

3.2.3.2.The purpose of the test:

Determine the percentage of water absorption by the bricks .

Tools and devices used:

Dying oven - sensitive scale - basin of water

3.2.3.3. Examination method

1-The test is carried out on (10) blocks and the average is taken.

2-The test sample is dried in a drying oven at a temperature of approximately 110 °C for 24 hours, after which it is cooled and weighed (w 1).

3- The sample is completely immersed in water with a temperature of (15-30) C. Then it is weighed within a period of (3) minutes from its removal from the water (w 2).

the accounts-: Absorption ratio = (w 2 - w 1) / w1 x 100 w1 = weight of the dry form.

w2= the weight of the saturated sample after (24) .

The Iraqi specifications M.Q.S. 25 of 1988 determined the percentage of absorption of bricks as shown in Table No. (1) above.

3.2.4. Test efflorescence

Efflorescence: It is salt deposits on the outer surface of the bricks. It occurs due to the permeability of the bricks and the ability to move the dissolved salts due to the moisture gained. After the moisture evaporates, the salts remain on the surface in the form of crystals. The characteristic of flowering is not limited to the presence of salt in abundance only, but also depends on the amount of moisture. The source of these salts is the soil used in the manufacture of bricks, especially when the soil is taken from the surface. The other source is the salts present in the ground water, which contains a high percentage of salts, used in the manufacture of bricks.

These salt deposits distort the external appearance of the buildings and cause the finishing materials to peel off from the inside and outside as a result of the crystallization, swelling and expansion of the salts, causing pressure on the finishing materials. The phenomenon of efflorescence affects the engineering facilities negatively, as the salts affect the properties of the bricks, which leads to cracking and fragmentation of the walls as a result.

3.2.4.1.To get rid of the efflorescence phenomenon, the following measures can be taken:

1- Excavating the soil before using it in making bricks.

2- Do not use water saturated with salts when building.

3.2.4.2.The purpose of the test:

Determine the percentage of salts in the bricks. Device and apparatus 1- Flat metal utensils with a depth of not less than 5 cm and containing distilled water with a height of not less than 2.5 cm.

3.2.4.3.Procedure method

The examination is carried out on (10) blocks and the average is taken.

1- Each brick is placed on its smallest end in a flat container (its depth is not less than 5 cm) and it contains distilled water with a depth of not less than (2.5) cm. It is left in the drying room with a temperature of (30 C). -15 ÿC) for a period of seven days, with the addition of distilled water whenever the container dries up, as in Figure No. (3).

2- The bricks shall be dried in the same room for a period of not less than three more days in the same pots, but free of distilled water.

The bricks are tested for efflorescence as follows:

1- Non- efflorescence: If no salts are seen on the surface of the sample.
2- Light efflorescence: If light salt deposits are seen, not more than 10% of the brick area.
3- Medium efflorescence: If salt deposits of more than 10% and not more than 50% of the surface of the brick are seen, provided that this is not accompanied by crumbling or flaking on the surface.
4- Heavy efflorescence: If the salt deposits cover more than 50% of the surface of the brick without crumbling or flaking on the surface.
5- It efflorescence very thickly: If the salt is deposited abundantly on the surface of the brick, and this is accompanied by crumbling or flaking of the surface, or both, with a tendency to increase whenever the sample is wetted with water.

The Iraqi specifications M.Q.S 25 of 1988 specified the efflorescence of the bricks as shown in Table No. (1). The area of the holes for the perforated bricks is subtracted when calculating the total area of the bricks.

Figure No (3) Test efflorescence for testing brick

If the total efflorescence area calculated for the brick is of the perforated type with dimensions (24 * 11.5 * 7.5) cm, determine the type of efflorescence in this brick is (80) cm and the number of circular holes is (10) for each face with a diameter of (2) cm. According to Iraqi specification.

The area of the brick faces = 2 (24 x 11.5) + 2 (24 x 7.5) + 2 (11.5 x 7.5) = 1084.5 cm^2

Area of openings for both sides = 2 x 10 [3.14 x (1)^2] = 62.8 cm^2

Net area of bricks = 1084.5 – 62.8 = 1021.3 cm^2

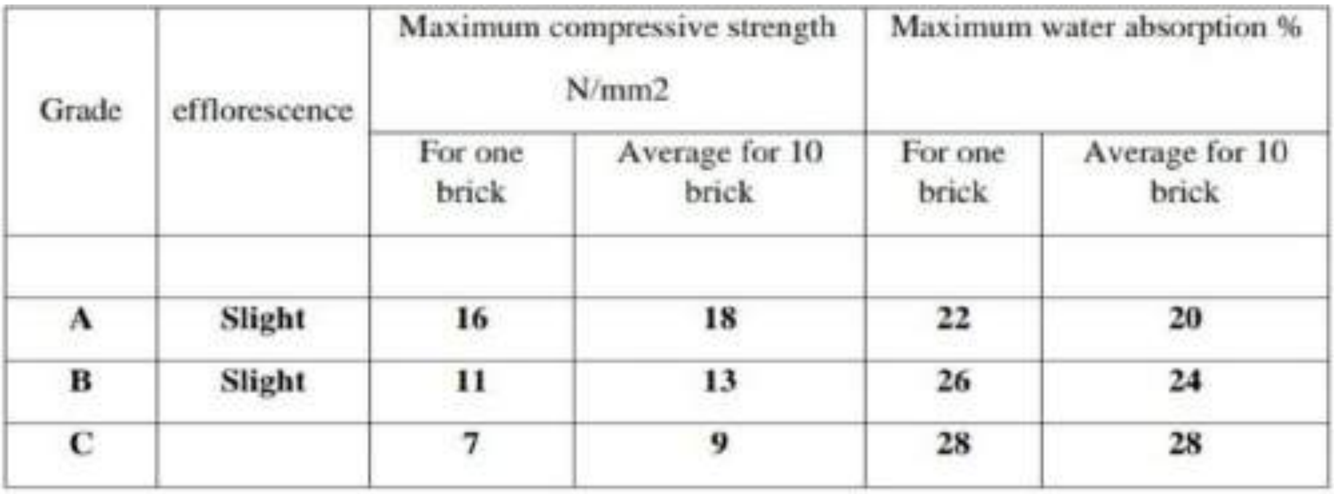
Percentage of efflorescence = (area of efflorescence /area of brick faces) x 100%

= 80 1027.7/ × 100 = 7.78% less than 10%, then efflorescence is light.

But if the efflorescence area is, for example, 120 cm, then the percentage of efflorescence is a Percentage of efflorescence = 120 1027.7/ × 100 = 11.6% more than 10%, so efflorescence is medium.

3.3. Previous tests and results

Table.1: Compressive strength, water absorption and efflorescence according to Iraqi, standard No. 25/1988



Grade	efflorescence	Maximum compressive strength N/mm2		Maximum water absorption %	
		For one brick	Average for 10 brick	For one brick	Average for 10 brick
A	**Slight**	**16**	**18**	**22**	**20**
B	**Slight**	**11**	**13**	**26**	**24**
C		**7**	**9**	**28**	**28**

Table 2: Previous results

Dimensions (mm)	length rate	width rate	height rate		general look	Surface Orthogonality: Orthogonal	Infiltration percentage: not more than 10% of the brick size
Tolerances (mm)	240	118	78			Side straightness: straight	Colour: Yellow to green
	+6	+3	+3			The cracks : a little	Burning uniformity: homogeneous

Table 3: Previous results

sample number	1	2	3	4	5	6	7	8	9	10	Average
Compressive strength (N/mm²)	13.4	15.3	12.8	13.4	12.9	11.2	13.4	13.2	12.2	12.2	13.00
Absorbance (%)	19.3	21.4	19.2	16,6	20	21,7	19	20	18.5	25	20.1

Chapter Four: Discussion and Results

4.1. Introduction

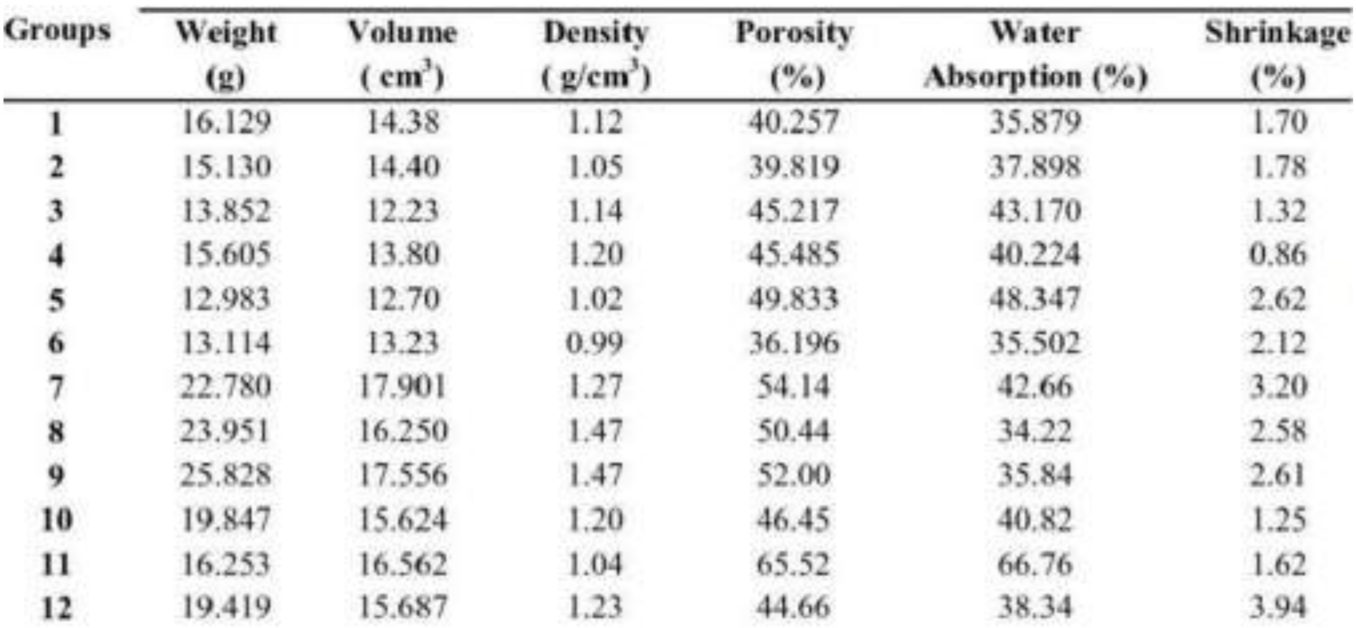
This chapter is divided into two parts, where the first talks about previous practical experiences, and the second part talks about the expert design program and everything regards to it.

Part One

4.1.1. Experimental Results

Previous research using the Expert Design program on physical properties, including porosity, density, water absorption , shrinkage, weight and Volume.

Table 4 : A Physical properties of bricks



Groups	Weight (g)	Volume (cm^3)	Density (g/cm^3)	Porosity (%)	Water Absorption (%)	Shrinkage (%)
1	16.129	14.38	1.12	40.257	35.879	1.70
2	15.130	14.40	1.05	39.819	37.898	1.78
3	13.852	12.23	1.14	45.217	43.170	1.32
4	15.605	13.80	1.20	45.485	40.224	0.86
5	12.983	12.70	1.02	49.833	48.347	2.62
6	13.114	13.23	0.99	36.196	35.502	2.12
7	22.780	17.901	1.27	54.14	42.66	3.20
8	23.951	16.250	1.47	50.44	34.22	2.58
9	25.828	17.556	1.47	52.00	35.84	2.61
10	19.847	15.624	1.20	46.45	40.82	1.25
11	16.253	16.562	1.04	65.52	66.76	1.62
12	19.419	15.687	1.23	44.66	38.34	3.94

1.Density: It was shown to be the best obtained in sample No. 8 and 9 through the previous research table.

2. porosity : Through the table of previous physical examinations, the porosity in samples 6 and 2 is the best that has been obtained**.**

3.Water absorption: the best reached in the table of previous experiments is in samples No. 8 and 9.

4.Shrinkage: The best obtained in the previous physical examination schedule is exactly the same In sample Nos. 4 and 10.

*** It is possible to choose samples No. 8 and 9 to create laboratory samples, according to what the program gave in previous tests.**

4.1.2.Soil chemical tests

Table 5 : Chemical Composition of Soil

Deep	**Amount of chlorides mg/l**	**T.S.S mg/l**	**SO3**	**Gypsum**	**PH**	**Orgaing %**
0 – 1.5	**25.99**	**18.4**	**0.01**	**0.022**	**8.51**	**6.30**
1.5 - 2	**19.99**	**2.4**	**0.20**	**0.43**	**8.36**	**7.43**
2 - 3	**17.99**	**14.4**	**0.20**	**0.43**	**8.30**	**5.36**
5.5 - 6	**13.99**	**9.6**	**0.10**	**0.22**	**8.41**	**5.60**
6 – 7.5	**15.99**	**16**	**0.10**	**0.22**	**8.25**	**7.30**
9.5 - 10	**13.99**	**16**	**0.07**	**0.15**	**8.56**	**2.64**

The second part

4.2. Software for Design of Experiments

Design Expert is a piece of software designed to help with the design and interpretation of multi-factor experiments. In polymer processing, we might use the software to help us design an experiment to see how a property such as tensile strength varies with changes in the processing conditions - e.g. changes in rotor speed or ram pressure. The software offers a wide range of designs, including factorials, fractional factorials and composite designs. It can handle both process variables, such as rotor speed, and also mixture variables, such as the proportion of resin in a plastic compound. Design Expert offers computer generated D-optimal designs for cases where standard designs are not applicable, or where we wish to augment an existing design - for example, to fit a more flexible model.

4.2.1. Statistical terms and concepts

4.2.1.1. Data

The factors that we vary in experiment can be divided into Process variables, such as the speed of an engine or the thickness of an adhesive layer, and Mixture variables, such as the proportion of resin in a plastic compound, or the proportion of fat in a chicken feed. With a mixture variable, the effect depends on the proportion of a constituent in the mixture, rather than on the absolute amount.

Process variables can be split into Continuous and Categorical.

- Continuous - can be varied freely over a range

– Engine speed, with speed varying from 1000 to 5000rpm

- Categorical - restricted to a few distinct values

– Filler, with a choice between pulverised fuel ash and glass beads

Categorical variables are sometimes divided into Nominal and Ordinal.

An Ordinal variable is a categorical variable in which the categories have a natural order - e.g. Small, Medium, Large.

A Nominal variable is one where no order is implied - e.g. a set of categories like colour or make of car.

4.2.1.2. Model

In analysing an experiment, we fit models relating a response or quality characteristic to a set of controllable variables. For continuous control variables, we often use a linear, factorial or quadratic model - for example. . .

Linear model $Y = \beta 0 + \beta 1X1 + \beta 2X2 + E$

Factorial model $Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 12X1X2 + E$

Quadratic model $Y = \beta 0 + \beta 1X1 + \beta 2X2 + \beta 12X1X2 + \beta 11X_1{}^2 + \beta 22X^2{}_2 + E$

Apart from the intercept, the terms in these models fall into one of three categories.

- Linear terms (Main effects) of the form βiXi

– model the average effect of varying a control

- Two-factor interactions of the form $\beta ijXiXj$

– allow the effect of changing a control to vary with the setting of another control

- Quadratic terms of the form βiiX^2i

– allow for curvature in the effect of a control on the response

Models for categorical controls often involve a set of terms to represent a single main effect or two-factor interaction, but the interpretation of the effects is similar.

4.2.1.3. Resolution

A full factorial design is one where the experiment uses all combinations of the levels of factors. Many designs involve running only a small fraction of a full factorial. This makes our experiments more economical, but results in what is known as aliasing between different effects. If two effects are aliased together, we can estimate their combined effect, but cannot separate out the size of each individual effect. For example, if A and BC are aliased, we'll be able to estimate the combined effect of A and BC, but we won't be able to obtain a separate estimate of A, or of BC. The resolution of a design gives an indication of the degree to which we're going to be able to separate out individual effects.

- Resolution III In a resolution III design, main effects are aliased with two-factor interactions. Unless the two-factor interactions are negligible, our estimates of the main effects will be biased.

- Resolution IV Two-factor interactions will be aliased in pairs, but we'll be able to estimate the main effects clear of any other main effects or two-factor interactions.

- Resolution V All main effects and two-factor interactions will be clear of other main effects or two-factor interactions. Unless the higher order interactions are sizeable, a Resolution V will often be almost as good as a full factorial.

4.2.2. Figures and Tables by program Expert Design.

Table 6: Physical properties of bricks by expert design program

Run	Factor 1 A:Weight g	Factor 2 B:Volume cm	Factor 3 C:Density g/cm	Factor 4 D:Porosity %	Factor 5 E:Wate Absorpti... %	Factor 6 F:Shrinkage %	Response 1 Response
1	25.828	17.901	1.47	36.196	34.22	3.94	9
2	25.828	17.901	1.47	36.196	66.76	0.86	10
3	25.828	12.23	1.47	65.52	66.76	3.94	9
4	12.983	12.23	0.99	36.196	66.76	0.86	8
5	12.983	12.23	1.47	65.52	34.22	3.94	7
6	12.983	17.901	1.47	36.196	34.22	0.86	17
7	25.828	12.23	0.99	65.52	66.76	0.86	5
8	25.828	17.901	1.47	65.52	34.22	0.86	10
9	12.983	17.901	0.99	65.52	66.76	0.86	8
10	12.983	17.901	1.47	65.52	66.76	3.94	17
11	12.983	12.23	1.47	36.196	66.76	3.94	12
12	12.983	12.23	0.99	36.196	34.22	3.94	10

Physical properties of Half-Normal Plot It shows the type of effect, where if the effect on the line is orange, the effect is positive, but if the effect is blue, the effect is negative as shown in Figure.1.

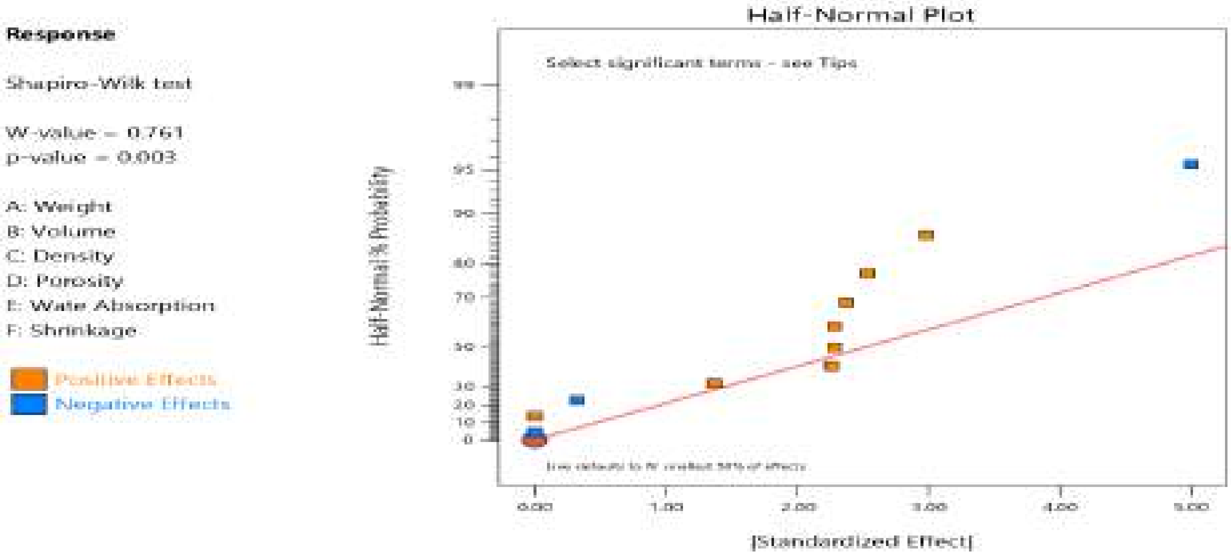


Figure.1 Physical properties of Half-Normal Plot.

The Physical properties of Histogram It shows the highest and lowest values obtained from the table where it was chosen number of data: 12 As Shown in Figur.2 .

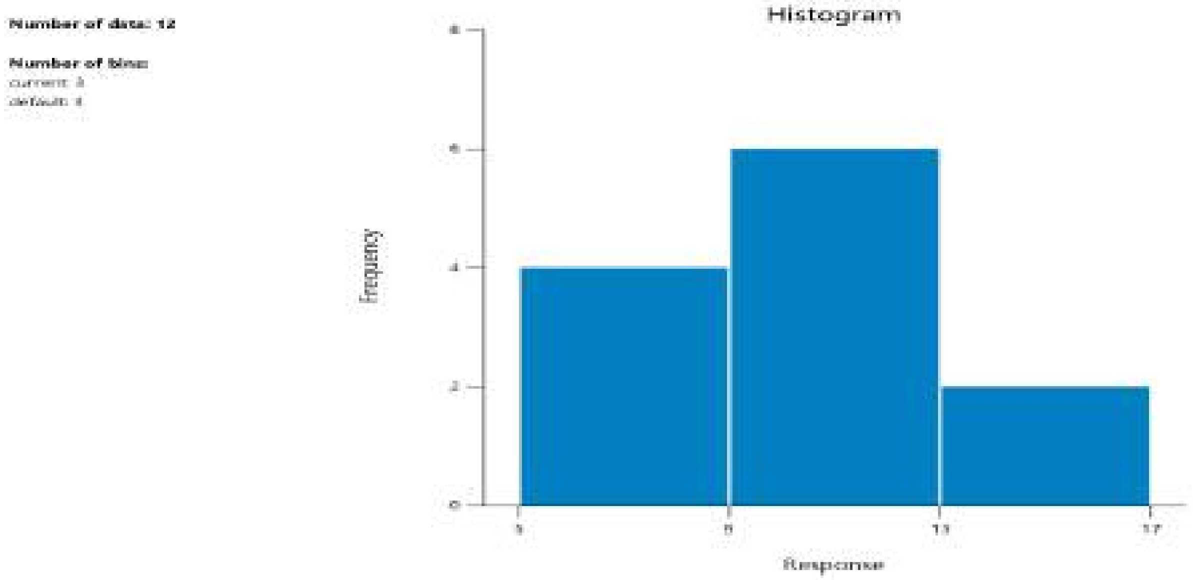


Figure.2 Physical properties of Histogram.

Physical properties of Pareto Chart is shows the rank and t-value of effect by showing two types of effect. If the effect is in orange it is positive and if in blue it is negative as shown in Figur.3.

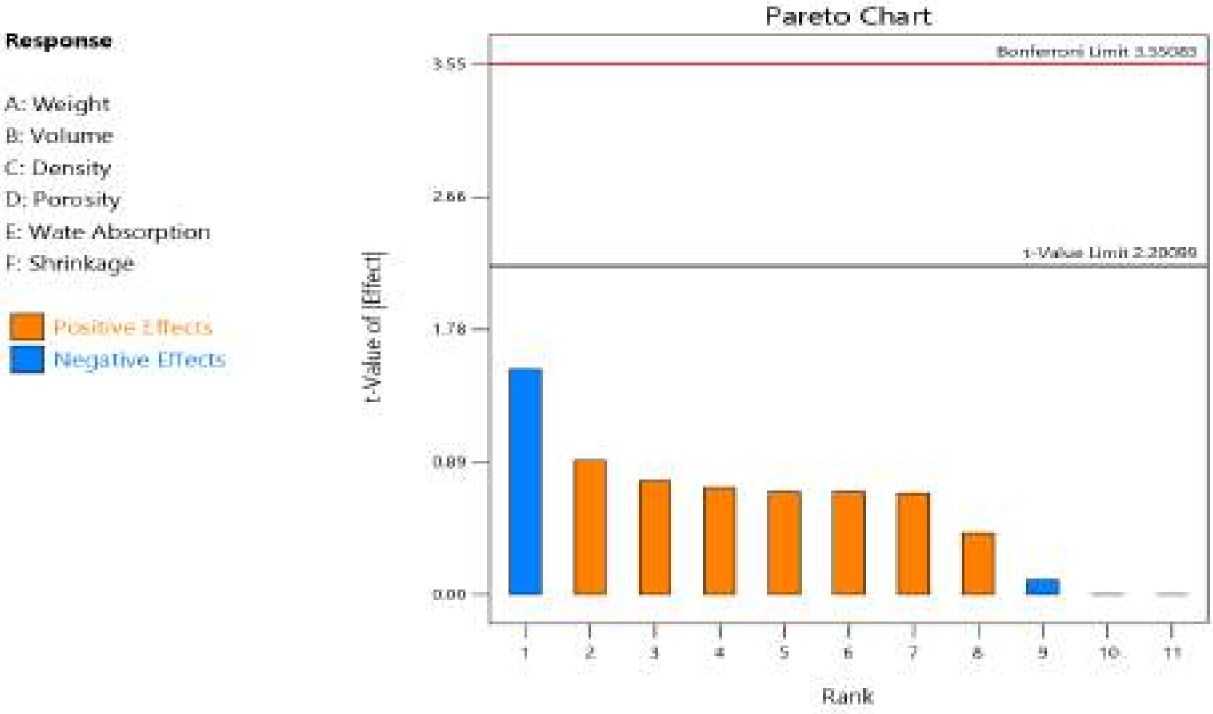
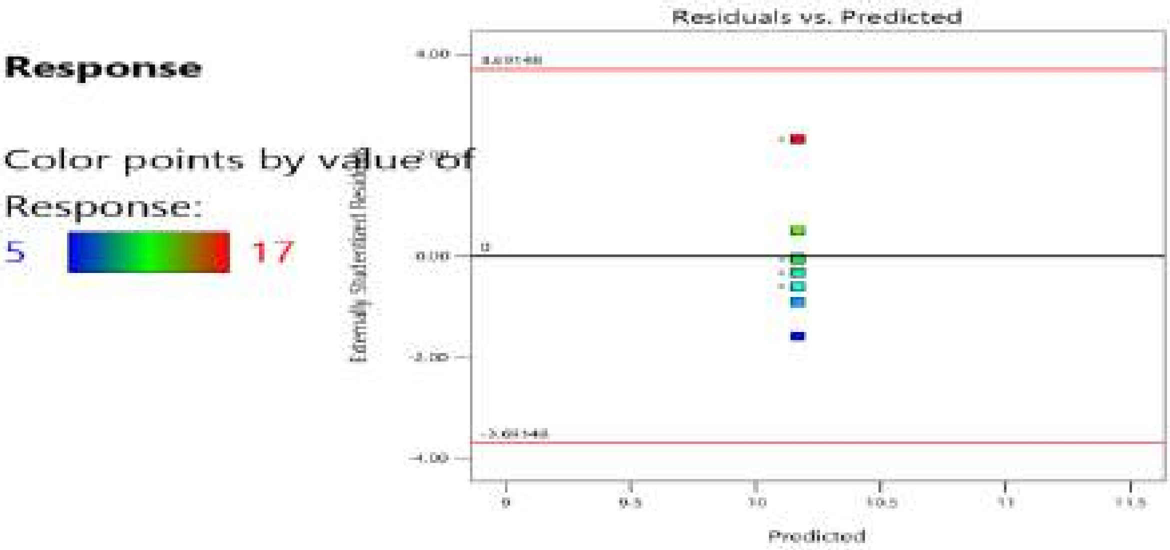
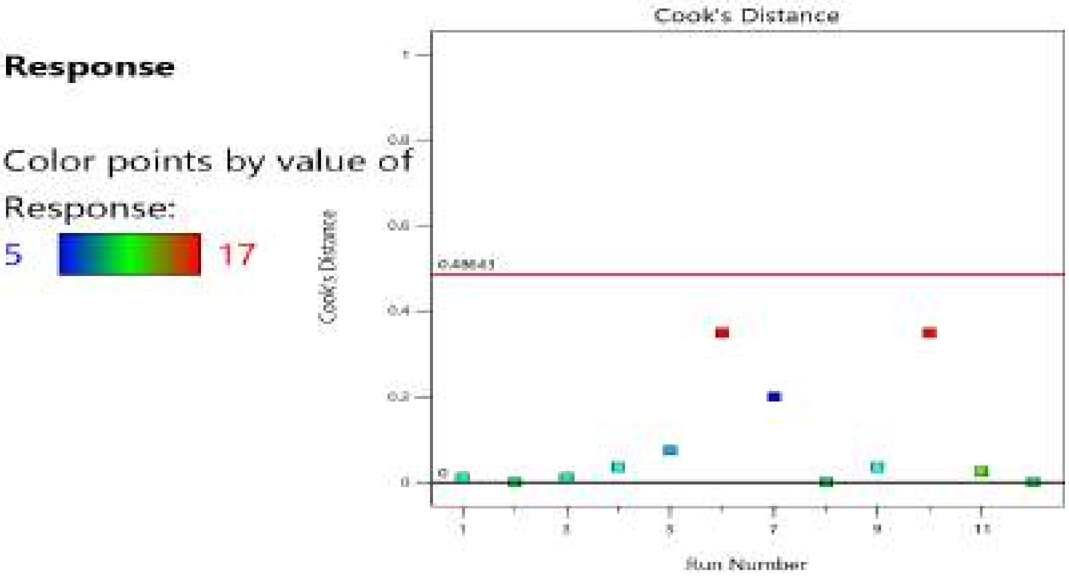


Figure.3 Physical properties of Pareto Chart.

The Physical properties of Residuals vs. Predicted Shown Color points by value of response between Predicted and Externally studentized residuals Shown in Figur.4 .

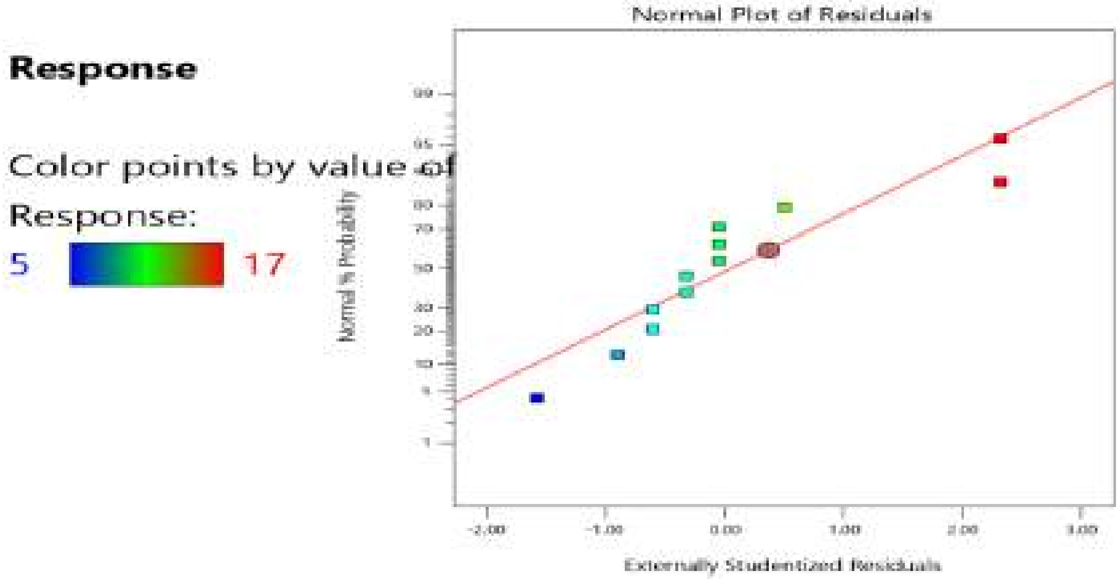


Figur.4 Physical properties of Residuals vs. Predicted.



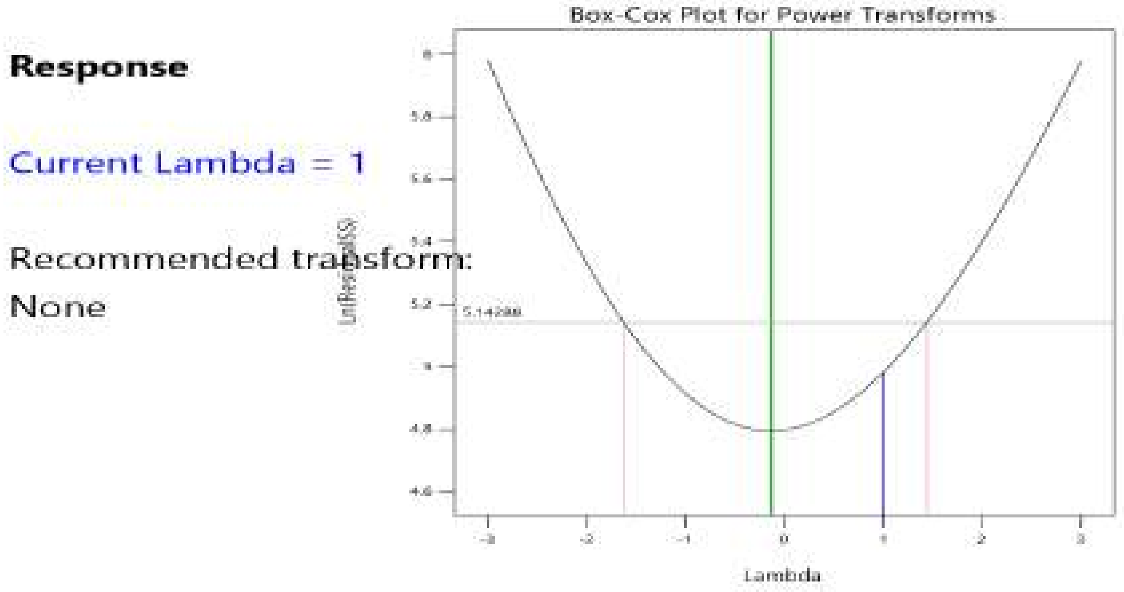
Figur.5 Physical properties of Cook's Distance.

The Physical properties Normal Plot of Residuals A straight line with colored dots between studentized residuals and normal % probability in Figur.6 .



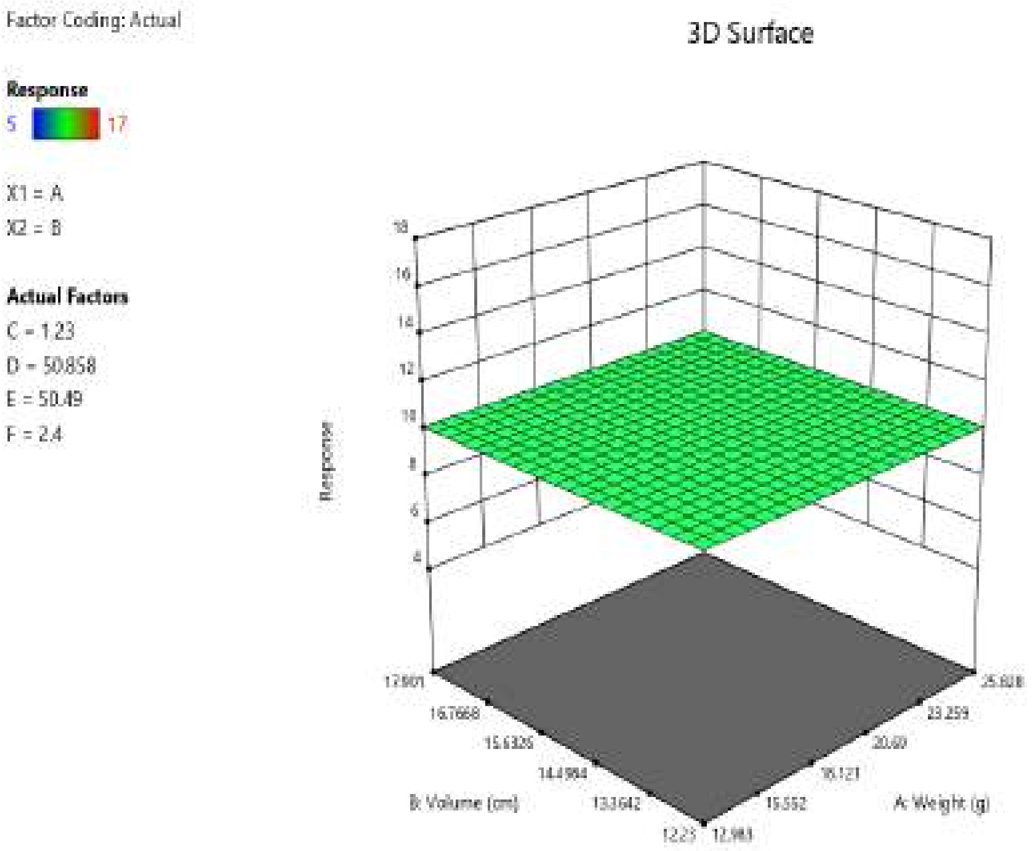
Figur.6 Physical properties Normal Plot of Residuals.

The Physical properties Box Cox for Power Transforms Shown Curve between Lambda and ln(Residuals)getting a Current Lambda= 1 in fig.7 .



Figur.7 Physical properties Box Cox for Power Transforms.

Physical properties of 3D Surface between volume and weight and value response in Figur.8 .



Figur.8 Physical properties of 3D Surface

Chapter Five : Discuss the results and recommendations

5.1. Discuss the results

Design – Expert provides a graph as well as a text output for residual analysis. The program determinesthe main effects for each factor as well as the interactions between the factors by changing Evaluate allfactors in parallel.

Surface model can be used Response Surface model (RSM to specify space Design using arelatively small number of experiments. RSM provides an estimate.

To value responses to each possible combination of factors by changing the values of All factors in parallel, making it possible to understand multiple surface Dimensions in non-linear shapes.

The optimization feature can be used to calculate Optimum operating parameters for an operation.

Design-Expert for Design of Experiments (DOE). Use this Windows®-based software to improve your product or process. It provides many powerful statistical tools, such as: Two-level screening designs: Identify the critical factors that affect your process or product so you can make massive improvements.

Design-Expert offers 3D rotation plots to easily display responsive surfacesfrom all angles.

Use the mouse to set flags and explore features on interactive 2D graphs. Our numerical optimization function finds the utmost desire to get dozens of responses at once.

5.2.recommendations

1. We didn't have time to sample a sample of the templates we got from the software I got from Expert Design.

2. The use of the Expert Design program shortened a lot of time for us compared to laboratory tests, as well as giving good results for making samples from it.

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