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DEVELOPMENT OF BRICK ARCHITECTURE: THE TRANSFORMATION IN ACCORDANCE WITH CONTEMPORARY DIGITAL TECHNOLOGY

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Abstract

Digital technology represents a force for innovation in various fields and disciplines, including architecture. Its impact extended to modernizing traditional systems which are associated with the culture of building and materials. In the local context, the material of brick and construction with it, is the most memorable traditional building systems, by its connection to collective memory and historical aspects. According to that, the research was directed towards this material and its traditional system in light of technological development, and its reflection on what is called (digital bricks) in contemporary architecture. According to that, the research aim was determined as: Exploration of how contemporary digital architecture deals with brick materials. To achieve the research aim, the research adopted an analytical descriptive approach, as well as a number of procedural steps: The first related to theoretical aspects by discussed the technological development and its impact on the development of architecture and building systems with bricks. The second was to build a theoretical framework for the indicators of the reflection of the transformations of digital bricks in contemporary architecture. And the third step was the practical study by analysing a number of projects approved for bricks as a building material in its developed form according to the vision of digital technology and the last procedural step (fourth) was elicitation the results and conclusions. According to that, digital technology has been able to develop traditional systems, and the research identified some of its impact in traditional building, which was changed the behaviour of bricks and its aesthetic values. This impact extended to the technique of implementation with a brick material, transforming the material to be a centre of creativity in several levels, which contribute to improving, developing and increasing the efficiency of this material as well as the ranges of creativity and the creation of shapes and configurations. The research also reached the features of the developed building brick system, which were innovation, novelty, uniqueness, evoking the historical reference - far from tradition and stereotyping - and the emphasis on creativity, excellence and quality.

Keywords: Contemporary architecture, Digital, Digital bricks, Digital technology, Technology and façade.

1. Introduction

The digital revolution replaced many traditional concepts in architecture through exchanging building materials and dealing with them. One of these materials is (bricks) which are traditional material present since ancient times. In the other hand, the digital revolution faced various challenges, the important one of them are the view towards traditional materials which connect with the identity of the traditional civilizations, local contexts and cultural values.

In the context of the duality of: (tradition, innovation) and (modernity, old), many inquiries arise about to the impact of technological development and its reflection on the development of traditional construction systems and materials, including the brick (as traditional material). This matter is directing the research aim towards: Exploration of how contemporary digital architecture deals with brick materials.

To achieve this aim, the research adopted an analytical and descriptive methodology that included four procedural steps: The first was about the theoretical aspects which related to the impact of digital technology on traditional construction systems and brick construction - as a special case - then discussed the similarities and convergences between brick construction and the digital parametric model. Then, discussed how digital technology deals with bricks, the transformation and development in it to be a material compatible with contemporary technology, and the levels of this development in the process of building architecture.

The second procedural step was to build a theoretical framework for the aspects of the reflection of digital bricks in contemporary architecture, by investing in the scientific knowledge achieved from the previous procedural step, and through analysing a number of specialized studies. Then, the research proceeded to the practical study by analysing number of projects, and then moved to the final procedural step which was elicitation the results and conclusions.

2. The effect of digital technology on traditional construction systems - bricks as a special case

Today's digital technology guides the architectural construction process and its impact on building materials. The big effect is convergence of technology modelling method with the building of brick walls which based on modules.

2.1. Digital technology approach with bricks as a building material

Digital technology is based on the modelling of the internal elements that make up the total system, and that convergence of (the brick) as a building material - the basic formative unit of the modelling process, where (the brick) represents a unified sub-unit with fixed dimensions, shape and size to form a total system (walls) based on the relationships between the dimensions of the brick And the relationships represented by the method of linking the joints within an organization based on the relationships between the units and the assembly pattern within a physical form orientation in different directions according to the design objectives, but it is related to semantic relationships that the designer is familiar with [1]. On the other hand, it is necessary to understand these relationships and deal with them - during the design and integrate them with the official design objectives - to define the architectural entity (styles) in terms of paradigm and adjust the geometric shapes without the need to constantly reconfigure them by drafting the basic rules for the brick units. Its geometry and patterns, and its incorporation into boundary relations, help in the design process by limiting the efforts of remodelling [2].

2.2. Modelling the construction process with bricks.

In contrast to the great flexibility provided by the traditional brick construction system due to the smallness of the initial building unit, which in turn achieves the modeling process and is achieved with it, but it is taking a long time. Here, digital technology offers itself strongly to remedy this aspect, in addition to the unlimited creative possibilities it offers relies on a developed formwork system to model the building away from traditional paving .Here, many studies presented strategies for building brick surfaces far from imitation, through what is called the individual style, in the Uruguay, double curved roofs were constructed in the (Atlántida Church) and screen brick walls were constructed, by controlling not only the bricks but rather controlling the way of working with them by shifting, rotating and doing Templates for whole classes and other templates for gaps between them [3]. Accordingly, the technology orientation can be confirmed towards improving the design process by the action of the material, by the modeling building processes and its implementation techniques, making moulds for the rows and the gaps between them and the frames for controlling the building as a whole.

3. Bricks Transformation into a Contemporary Material through Activation

Within the framework of developing traditional brick construction systems, technology is directed towards the construction process in addition to the brick as a basic unit in the modelling-based construction process.

3.1. Transformation in shaping, composition and bonding (Automation of the design process)

Parametric design achieved wide changes in the assembly of building blocks by storing data for the coordinates of any simple body to produce new shapes. With the help of digital programs, multiple alternatives are generated in which the designer manipulates the same component object or parameter to develop their use in various ways to produce creative results [4].

The design process in the digital environment focuses on the representation of the emotional dimension data of the bricks, especially its light, shadow and colour patterns related to the productive environment and the local context. Development of the graphics and craftsmanship of traditional bricks [1]. It is also based on a general methodology for translating design experience into an appropriate set of parameters that can generate the behaviours required in (BIM) (building information models) tools, so that all the different components of the wall are combined and act as a single entity as a result of preserving the definition associated with the architectural entity as a whole, and to include experience

The design adopts the basic unit required as a parametric component that contains engineering relationships and deals with external rules to represent the assembly of building components, and by changing the design, these boundary relationships will allow changes automatically in order to organize the assembly within the interconnected engineering structure and its components.

Thus, components have to be designed according' to their appearance and semantic relationships within their specified scope, so the methodology required implementing patterns on brick walls u7'yyyul be a component-based frontier technology to generate the geometry of the entire group while providing accessibility to each of the components. These boundary relationships for generating brick patterns should maintain the geometric consistency of the components within the assembly [4]. An example is the (Gantenbein Vineyard Façade) designed by Gramazio and Kohler and the (Design Studio II) building for Southern Polytechnic University designed by Cooper Carry Architects with a methodology to automate the design process using (yaw) technology [5].

3.2. Post transformations (transforming the brick through parameterized techniques to produce data)

This development is based on the initial unit represented by redesign bricks. Under this approach, the building unit maintains its formal properties and dimensions, in exchange for introducing two dependent variables, the first: creating a hole to place the post-tensile reinforcement inside the brick, the second: the engineering contrast while preserving the ability to produce under low-tech manufacturing techniques by adopting a one-sided rotation strategy to generate a new, geometrically complex brick based on the function and the result is a new module called the "deformed brick". By means of digital control, the position of the rotational axis of the rotated brick is modified and the angle of rotation changes the amount of twisting performed by the deformed brick. This is a breakthrough in the brick by modifying the logic and standards into parameters Encoded within digital software using McNeel Rhinoceros and Grasshopper as a digital environment for relational modelling [6].

3.3. Behavioural Transformation (smart brick)

A change in the structural behaviour of the traditional brick system is achieved through innovating the concept of "interlocking system" to make construction more economical and faster compared to traditional construction containing connections based on changing structural behaviour, such as Sparlock, Meccano, Sparfil, Haener, Putra (SIB) and Hydraform where the focus was on analysing the behaviour of the contact area between the bricks due to the absence of filling materials between the pieces is shown in Fig. 1. the behaviour of the dry joints is vital design parameters that must be measured and in light of this characteristic, contemporary brick wall construction is faster and requires less skilled workers as well as improving build ability, performance and cost [7].

Fig. 1. The application of bricks sensoring techniques [8].

After the application of artificial intelligence, wireless technologies, and specialized sensing techniques, “digital technologies were able to meet the challenges of integrating wireless sensing into traditional building materials such as bricks, enabling the monitoring of environmental parameters such as strength, pressure, temperature, tilt, humidity, sound, chemicals, stress, etc., to enable the building blocks. The simple basic structure that forms modern structures provides long-term intelligence related to the health of the occupants and the health of the environment around them [8]. The wireless node jammed in the bricks as shown in Fig. 2. especially in the walls of fire curtains in the stairs or exits of the building can provide analogy conversion. To digital, sensor capture, signal transmission and data transfer to “mother-node” data processing program to reduce energy consumption and cost through adaptive transmission capacity, exception and demand-based reporting. Environmental resources such as thermal charging, solar and inductive energy are investigated to implement design objectives, especially those related to cost and safety [9].

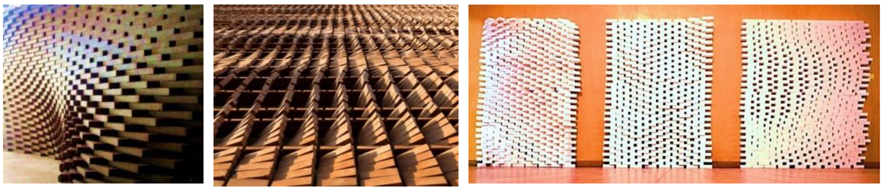

Fig. 2. Horizontal, vertical displacement and rotation to develop contemporary brick design models [6].

3.4. Digital brick manufacturing and the additive fabrication process

Under the conditions of digital manufacturing, modifications have been reached in the way the clay is manufactured, including changing the shape of the mold and inserting a hole to accommodate the post-tension system during assembly and producing it using an alternative craft technique by grinding the recyclable expanded polystyrene because it is cheap, lightweight, and faster .

In the mill, for mass production, the moulds are made using solid wood, which provides accuracy and resistance over time, as well as making adjustments in the production path such as adding texture where the clay copies the roughness of the mold, increasing its ability to capture light while expressing the curvature and joining of the surface. Material. An interlocking switch was also created to add structural rigidity [10]. Emphasis was placed on the additional manufacturing of building components by means of digital tools with the intelligent inclusion of differentiated information through the selective positioning of materials and spatial difference [11].

By using Six-axis industrial robots have achieved the highest flexibility because the construction logic to achieve architecture depends on the principles of building addition, such as stacking bricks, as it provides tremendous advantages over digital manufacturing processes over subtraction as well shown in Fig. 3. [12]. The robot can place each brick differently without exerting additional effort by applying various information to a wide range of elements such as logical information, building link information, assembly standards and fixed properties, thanks to programs that integrate architectural design knowledge with material knowledge and its construction processes within the digital environment by focusing on collecting and linking "common sense." With knowledge "down to unfamiliar patterns, by referring to known patterns or historical examples, retrieving construction information, costs, past experience and new features, to arrive at a high-quality creative work." Low cost level [11].

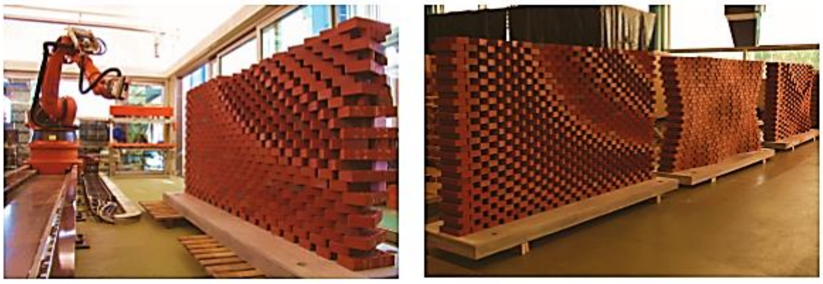

Fig. 3. The ability of robots to stack, interlocks, and put bricks differently with minimal effort and time [13].

3.5. Transition from traditional brick systems to digital bricks

According to the foregoing, digital technology has revolutionized traditional brick systems towards digital bricks with two levels: The first is related to developing the design process through developing the design platform with adopting what is termed (border design). Here, the reversal of this aspect can be confirmed on the body of brick, grouping rules and relationships and the mechanics of shaping. And the second level is related to development of Implementation, by oriented toward (Digital manufacturing). This level can be done by tows templates, Gaps templates, frames and frames templates. According to that, the traditional brick manufacturing process transforms from simply assembling and stacking units to a (modelling process), in which endless possibilities can be realized formally, by changing the pattern of unit assembly. So, the process of building bricks turns into a creative process, as shown in Fig. 4 [14].

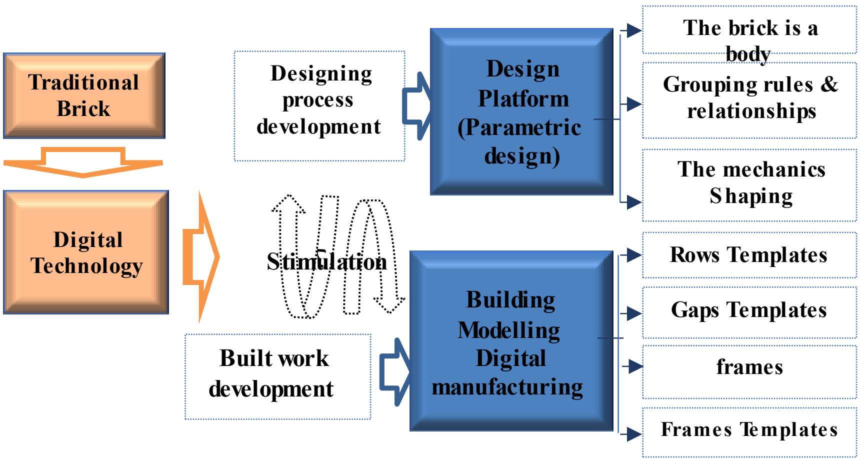

Fig. 4. Stimulation foundations traditional bricks through Digital technology.

4. Theoretical Framework for the Transformations of Traditional Brick to Digital Bricks through Digital Technology

According to the foregoing, it is possible to confirm multiple levels of transformation in dealing with bricks according to technological developments, these transformations range from a focus on the formal aspects of the brick, to another on behavioural transformations that focused on the behavior of the bricks as a building system and a sensing system, while technology, in a part of them, directed towards aggregate transformations, which focused on the structural and relational aspects of the bricks, as well as the operational transformations through digital manufacturing and the manufacture of digital additives. Which focused on craftsmanship, precision, skill and logic of building bricks with the help of robots.

For the purpose of enriching the knowledge aspect and enabling the derivation of a theoretical framework regarding the transformations of traditional bricks thanks to digital technology into digital bricks, the research will analyse a number of studies related to the topic, as follows:

4.1. Schumacher Study (2011) [14]

The study posited contemporary architectural spaces implemented by applications of digital deformed bricks according to need, away from the speculation of designers. It also reviewed how to adapt the wide brick models and according to the designer's philosophies away from the traditional square floor space with a straight direction, and towards the curved, folded spaces as an independent material system by adopting the subsystems and the relationships between them [14].

The study dealt with some indicators of the reflection of the integration of bricks with digital technology, including energy saving efficiency and reducing its consumption based on its effect on the thermal mass of the building as a whole, shading through its formations, the method of achieving protrusions and self-shading of prominent bricks on others, as well as its decorative appearance aesthetics that went beyond expectations using the parametric approach. To design and manufacture bricks with computational techniques and simulation programs (DIVA/Archsim) to enhance the formative capabilities of bricks at a low cost. Interactive brick patterns are created with knowledge-rich BIM systems using image analysis and analysis of the relationship between structural representation and its physical use to provide non-standard patterns by assembling new, adaptive and highly innovative shapes. High accuracy with daylight analysis, using genetic algorithms and placing solar energy screens to improve daylight and using shading systems for decorative patterns, which reflect the connection method and the values of the protrusions on reducing energy consumption by 60% in hot dry areas [14].

4.2. Hirai (2014) [15]

The study focused on the peculiarity of the digital fabrication of bricks, as it adopted addition processes instead of subtraction operations to confirm the concept of depositing materials in the places where they are needed without generating wastes. Here, both the environmental impact and the enhancement of efficient production as well as the reduction of costs are achieved.

According to the study, the principle of addition allows for a distinct design, unlike the traditional construction logic for layers, where the wall is built, for example, in series layers (the outer layer is resistant to weathering, insulation, load bearing layer, fixtures, inner finish). Here, the additive manufacturing process allows for various functional properties to be enhanced throughout the component. Here, the additive manufacturing processes allow the designer to control many changes in the brick building, including those related to the amount of load and the thermal properties of the building element, This approach allows creating a locally diverse composition and microstructure for the composite material, so that a difference in the properties of the materials is achieved, which allows for better accuracy and a higher level of detail, thus achieving a greater range of possibilities for integrating the functional properties in the component. Directly on manufacturing speed and reducing the cost of ingredients in exchange for enhancing the overall appearance of the product [15].

4.3. Al-Fakih (2014) [6]

The research discussed an aspect of digital design techniques and their integration with local technologies, focusing on the process of producing bricks in light of local technology as a way to achieve engineering differences and functional complexity in local projects, which is characterized by the inclusion of clay bricks as an essential part of the traditional building culture.

In this context, the study discussed the challenges of creating an innovative system in a local context in which digital manufacturing is not an economically viable option, and a challenge in adapting this technology to the means of implementation and local employment.

The research was directed towards developing an effective procedure that could be followed by using different types of bricks, which promoted the rethinking of bricks as a contemporary material, thus paving the way to re-place it on the agenda of avant-garde architecture. Accordingly, it proposed new building systems that could coexist with traditional bricks and simplify their introduction into Architectural practice. The new brick acts as an add-on to achieve complex geometry at the local level as a means to energize brick building.

The study concluded that developing new physical systems represents a challenge in reconciling digital design with material significance and design culture and enhancing understanding of contemporary tectonics [6].

4.4. Mohamed (2017) [16]

The study focused on the role of smart materials, as part of the smart structure system, and its role in developing contemporary building technology. The most important aspects that these materials achieve is their ability to respond and sense the environment.

The smart materials such as: (smart concrete, smart bricks, and smart glass, etc.) are the main elements in smart components, smart green surfaces, smart paints and coatings, and more. Here, these elements contribute to controlling aspects of the climate, lighting and heat, and achieving appropriate conditions for the building, at the same time they contribute to reducing the negative environmental impact, depleting resources, providing environmentally friendly and inexpensive energy, and responding to the challenges resulting from natural disasters such as earthquakes, storms, hurricanes and others.

The study confirms that the development of smart materials makes them a living system in terms of interaction, and in light of the melting of the boundaries between science, technology and architecture. Consequently, the development of smart materials, including smart bricks, is a result of the interaction of science, architecture and technology. Here the study presents a "new innovative design model" to achieve sustainability by linking and interacting with architecture with materials, as these materials guide architecture and constitute a major movement for innovative architectural design, by giving new possibilities and ability to adapting [16].

Table 1. Test model specifications and test conditions.

Study	Variables
Schumacher (2011) [14]	• Digital brick applications • The ability of digital bricks to the responding and adapting according to architectural trends • The ability of digital bricks to achieve diversity of facades by function • The realization of form possibilities for digital brick compared to capabilities of traditional bricks. • Reflection indicators of brick integration with digital technology • Improved digital brick properties such as: efficiency and energy saving, balancing effect with building thermal mass and providing shading through melding pattern. • Achieving digital bricks to new aesthetic dimensions, enhancing the decorative appearance, formative capabilities, and achieving non-standard and innovative styles through the adaptive shapes. • Mechanisms to achieve digital bricks and their integration with the different systems of the building. • Analyse the relationship between the structural representation of digital brick and its physical use.
Hirai (2014) [15]	• The peculiarity of the digital fabrication of bricks. • The adoption addition processes instead of subtraction operations without generating wastes and to enhancement the environmental impact, the efficient production and reduction of costs. • The advantages of additive manufacturing process: enhanced various functional properties throughout the component, the control of many changes in the brick building, enhanced the building's characteristics like load and the thermal properties, creating a locally diverse composition and microstructure for the composite material, allows for better accuracy and a higher level of detail and speed and enhancing the overall appearance of the product.
Al-Fakih, (2014) [6]	• Digital design technology and its integration with local technologies • Adaptation of innovative systems in the local context and the possibilities of making them economically viable and adapting with the means of implementation and local employment. • The possibilities of bricks under digital technology in achieving complex geometry at the local level as a means to revitalize brick construction. • The role of digital fabrication in improving the functional properties of digital bricks. • Improvement characteristics of digital bricks and improvement of aesthetics aspects.
Mohamed (2017) [16]	• The importance of smart materials (including smart bricks) in developing contemporary building technologies. • The characteristics of smart materials such as responding to the environment and sensing of it. • Smart materials applications, such as: smart components, smart - green surfaces and smart coatings, • The contribution of smart materials in controlling aspects of the climate, lighting and heat, achieving appropriate conditions for the building, reducing the negative environmental impact, not depleting resources, providing environmentally friendly and inexpensive energy, and responding to the challenges resulting from natural disasters.

5. Theoretical Framework of Research

In accordance with above, and through the collection of vocabulary and concepts related to the topic, the research concluded a theoretical framework that combines aspects and dimensions of the transformations of traditional bricks towards digital bricks, as this framework came in Six main vocabularies, which were : (Creation and Innovation Indicators, Expression Indicators, Economic indicators, Performance indicators, Environmental indicators and Sustainability and Construction and service indicators), and all of that were including number of secondary and sub-vocabulary as shown in Table 2.

Table 2. The theoretical framework of digital bricks.

Creation and innovation aspects	**Create new architectural models**	**Non typical entities architectural brick**
		Non-standard brick structures
		Non-repetitive (variety)Bricks areas
	Invent new systems	Complex organizational patterns
		Curious and unusual complex compositional patterns
.	Creating an architectural language (Compositional properties)	Continuation
		Curvature and folding
		distortion
		Stacking and intertwining
		Perforation versus solidity
Expression aspects	Accuracy and abundance	Confirm the cultural dimension
	the Semantic	Confirm the digital tectonics aesthetic
		Confirm the historical dimension
		Confirm the social dimension
		Confirm the temporal-spatial affiliation
Economic aspects	Reducing costs	
	Manufacturing speed	
	Speed up the implementation	
	Durability	
	Efficiency	
	High resistance	
	Controlled indoor environment determinants	Natural light
		Shadow and shading
		Ventilation
	Thermal efficiency	Thermal barriers
		Vertical gardens
		Three-dimensional screens
		Natural screens
	Humidity efficiency	Sequential layers and Braided curtains
	Noise control	Sequential layers and Braided curtains
	Control of waste production	Reducing waste production
		Recycling waste
Construction and service aspects	Innovational structural system	
	Raise Strength and durability	
	Integration with services and hide them	
	Reducing the load of building components	
	Organization the load distribution	

6. Practical Study

This paragraph represents the third procedural step related to the analysis of contemporary applied projects, as the study intended to elect a number of projects.

These projects were elected depending on its uniqueness and having functional and contextual diversity.

6.1. Termitary house In Vietnam (2014)

The designer focused on local context by adopting the glazed bricks, but through the digital technology achieved an interface screen to enter light and natural air as illustrated (Fig. 5) by reorganizing the bricks proud with a more vibrant perforation pattern, as the openings provide aesthetic visual values, as the brick walls appear bright red in the morning. But after sunset, it becomes purple, and despite the severe seasonal changes in the region due to its location within tropical spaces, the design of the brick walls ensures that the residence remains comfortable under the digital assistive programs [17].

The reflection of the integration of low-tech digital technology into the bricks by providing a healthy and appropriate interior environment that fulfils the comfort requirements represented by lighting and natural ventilation, as well as the performance aspects associated with the vitality of the building for the diversity of scenes between day and night, which strengthened the aesthetic aspects, especially those that are confirmed to embody the designer's thought at the deep level rather than the superficial representational level.

Fig. 5. Termitary house [18].

6.2. Courtyard house in Beijing (2016)

The design enables the cultural aspect to be regionalized, as the fourth corner of sustainable development is the increasing interest of contemporary architectural discourse in cultural archaeological values as illustrated Fig. 6. Field work in China has confirmed that current Chinese housing designers and builders lack basic knowledge about their history and architectural heritage in order to honour architectural culture. Chinese modern facilities have been integrated to meet the requirements of today's living with the culture of brick building to combine privacy with society (sustainable structure) with the spirit of the current era, and thus ArchStudio designed it in a new style confirmed by the transformation of corrugated bricks from floor to ceiling in the middle of the traditional yard as they wanted to convert the small yard into A dynamic shared space that literally connects indoor and outdoor life, thus achieving a renewal in the traditional interior courtyard design through twisted brick design [19]. The purpose of this project is to upgrade the infrastructure needed for a contemporary lifestyle, thus transforming this traditional courtyard that used to be a residence mainly into an urban public place Attractive within Beijing. The reflection of the incorporation of low-tech digital technology into bricks is the actual embodiment of the cultural dimension of the building instead of its extinction, in what has achieved a contemporary architectural discourse in which the present and the past continued through modernizing a traditional architectural element from a small to large scale [20].

Fig. 6. Courtyard house [20].

6.3. Farshad Mehdizadeh and Ahmad Bathaei-Termeh office building in Iran (2015)

The designer focused on the urban horizon in the design of the building, as he was able to create a different connection with the urban space as well as linking different functions separately and directly to the urban space by converting the office floor to a brick ceiling for sales spaces by curving the brick surface, which earned it the function of stairs and walkways as shown in Fig. 7 [21].

The bricks ceiling also achieved a garden for outdoor work parties, and the brick façade was a continuous covering system made of local bricks decorated with modern techniques from local and traditional layers of brick in order to match the urban context. The building was designed to communicate with public places in the city and is affected by many public squares in Hamedan, which are connected to wide streets. Therefore, the architects decided, through the design of the brick roof, to emphasize the relationship between the interior of the building and the street [22]. After analysing the above description, it became clear the role of digital bricks in creating new relationships to solve the problems associated with transforming the architectural dimension to urban after the ability that the bricks acquired represented by combining the horizontal and vertical level with a high flow despite the difference in scale between them, so that the interior and exterior communicate with an innovative relationship that confirms the dynamism of the identity of architecture [23].

Fig. 7. Termeh office building [24].

6.4. SAHRDC office building in India (2005)

The designer faced the problem of sound and visual pollution of street activity as well as the low budget, so the main generator of the design was to reduce the heat gain and achieve privacy for spaces due to the small area of the site and the proximity of the mass to the street with reduced noise [25]. So, the local brick material was adopted to establish the design by creating atypical models that form a thermal barrier with structural interconnectedness. To distribute the load and be as an outlet by regulating the shading to reduce the heat gain and punching for natural ventilation while creating a complex pattern for a brick screen that communicates with the value of the traditional bricks as shown Fig. 8. That is achieved through computer modeling of the brick unit and its rotation and the horizontal entanglement between the units is mainly through the overlap between the units and in The porous central part of the façade to reinforce the brickwork horizontally by placing a thin bundle of reinforced concrete (95 mm x 125 mm) along the cavity resulting from the missing central brick in response to the economic, social, cultural and environmental parameters of the project [26].

According to the analysis sample description, the reflection of the integration of digital technology with the bricks on the sustainable side of contemporary architecture with its three pillars, environmentally by introducing digital bricks a punch cover to regulate heat and ventilation, and economically as it enables the bricks to reduce the heat gain, and socially by achieving the societal specificity of the bricks as well as achieving the fourth dimension Sustainability represented by the cultural dimension.

Fig. 8. SAHRDC office building [27].

6.5. The boys' hostel in India (2017)

The design achieved first place in the 2017 RTF Sustainability Awards, as the bricks were designed parametric to surround the building as a secondary leather for the hostel and add a unique character and texture to the building's façade. Rotation angles for each brick were stimulated with software (Ecotect, Grasshopper) to reduce solar radiations and direct heat gain on the interface. The brick skin also accommodates terraces that increase student interaction, as illustrated as shown in Fig. 9. These balconies also act as a thermal barrier between the indoor and outdoor spaces [28]. In addition to the interaction of students inside the internal spaces that leak out and interact with the surrounding landscape. It opens to the landscape that abuts the building (the indoor-outdoor relationship). Special emphasis is placed on the outdoor life that coincides with the indoor spaces. The assembly of the bricks was modified, achieving protrusions to reduce the solar heat gain by 70% by shading the southern façade according to climatic considerations and based on the analysis of solar radiation and air movement to develop a second brick skin on the façade that allows thermal insulation and light transmittance at all times, to create a unique pattern of different shade and light. In every space and room, each floor rotates with a different axis of rotation to create a new architectural language [29].

The analysis of the sample description showed the reflection of the digital bricks in increasing the quality and performance of contemporary architecture through the varied brick covering between the perforated and solid style, which confirmed the (light-shadow) plot to achieve the four sustainability pillars.

Fig. 9. The boys' hostel [30].

6.6. O'Donnell + Tuomey in London (2013)

Contemporary Flemish brick walls achieved a modern model that varied between (hardness – lace) to allow natural light to penetrate during the day into the interior spaces and to infiltrate the lighting outside at night, which achieved an impact on the style of the façades as shown in Fig. 10. [31]. Through the barometric design of the bricks by manipulating the values of the parameters (bricks) to achieve a style The brick screens located in front of the windows to reduce the heat load of the solar rays in front of the building as well as achieve natural ventilation, as well as achieve a contextual link with the surrounding to enhance the aesthetic aspects of the infinite cricket material used in the buildings of the context as a whole, but it took different patterns related to the spirit of the digital age [32].

It was found that the reflection of the integration of low-tech digital technology with bricks has increased the quality of contemporary architecture, as the floor screens that weave the weaves of hardness and perforation provided a healthy and comfortable interior environment by providing light, shade, heat and adequate ventilation, as well as providing communication intermediate spaces between the interior and the exterior "visually and functionally", achieving a spatial connection. And temporal to express the spatial belonging to the context and continue with the spirit of the times together.

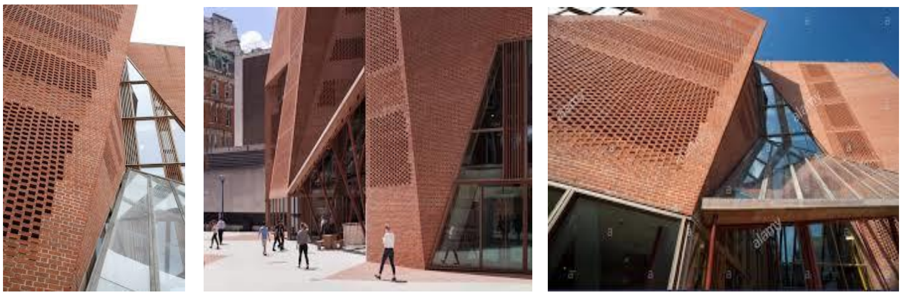

Fig. 10. O'Donnell + Tuomey in London [33].

7. Application Results

Complementing what was mentioned in the practical study, this paragraph was applying the theoretical framework to the selected projects. Table 3 shows the reflection of the application in the selected projects.

This application was identifying the most important indicators and conclusions for the practical study, which showed the reflection of the incorporation of digital technology, which transform the traditional brick to digital bricks. The main issue, in this context, was the clear discrepancy in the extent of digital technology investment, for the selected projects, against the capabilities and characteristics of digital bricks that were extracted in the theoretical framework.

According to that, the applying of theoretical framework for the selected projects showed the appointment of formal aspects, with an emphasis on the mental image associated with traditional bricks and specific formulas have been adopted to achieve the indexes of creativity and innovation. Here, the cultural and historical factor was the decisive factor for determining the direction of the brick's development.

Table 3. Application of the theoretical framework of digital bricks to the selected projects.

Vocabulary of the theoretical framework			**selected projects**					
			1	**2**	**3**	**4**	**5**	**6**
Creation and Innovation Indicators	Create new architectural models	Non typical entities architectural brick						
		Nonstandard brick structures						
		Non-repetitive (variety) Bricks areas						
	Invent new systems	Complex organizational patterns						
		Curious and unusual complex compositional patterns						
	Creating an architectural language (Compositional properties)	Continuation						
		Curvature and folding						
		distortion						
		Stacking and intertwining						
		Perforation versus solidity						
Expression Indicators	Accuracy and abundance the Semantic	Confirm the cultural dimension						
		Confirm the digital tectonics aesthetic						
		Confirm the historical dimension						
		Confirm the social dimension						
		Confirm the temporal-spatial affiliation						
Economic indicators	Reducing costs							
	Manufacturing speed							
	Speed up the implementation							
Performance indicators	Durability							
	Efficiency							
	High resistance							
	Controlled indoor environment determinants	Natural light						
		Shadow and shading						
		Ventilation						
	Thermal efficiency	Thermal barriers						
		Vertical gardens						
		Three-dimensional screens						
		Natural screens						
	Humidity efficiency	Sequential layers and Braided curtains						
	Noise control	Sequential layers and Braided curtains						

	Control of waste production	Reducing waste production Recycling waste					
Construction and service indicators	Innovational structural system						
	Raise Strength and durability						
	Integration with services and hide them						
	Reducing the load of building components						
	Organization the load distribution						

8. Conclusions:

The results of applying the theoretical framework to the selected samples showed the effect of digital technology in activating the local brick material and raising the performance of contemporary architecture through a set of points represented by:

- The role of technology in architecture, today and in the future, goes beyond the role of the executor of architecture to draw its image and define its path. This influence extends to the relationship of architecture with its identity, affiliation and its relationship with heritage and traditional building methods.
- The digital technology had developed and impacted the traditional systems; this effect extended to the technique of implementation with brick and transformed the material to center of creativity in multiple levels.
- The behavioural transformations of digital bricks achieve new features that raised the quality, performance and efficiency of architecture.
- Automated operational transformations have changed the logic of building with bricks, achieving high levels of innovation, quality, accuracy and speed of implementation that transcendence traditional craftsmanship system.
- The evolution towards digital bricks in contemporary architecture has promoted a number of goals that enhance and develop the course of architecture at physical level and non-material level relates to the function, economic aspects, performance dimensions, implementation enhancement, sustainability, aesthetic dimension, and finally the dealing of architecture with its surroundings and environment
- In the detail aspect - the direction towards digital development of brick in contemporary architecture has enhanced the opportunities for innovating and developing the characteristics and details, as heat gain, insulation, transmittance, optical properties, formation and aesthetics through important mechanisms which controls of pattern and the control of projections and silhouette gaps.
- These mechanisms lead to reduce energy consumption and control the impact of sound and pollution, which lead to achieving sustainability.

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