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Evolution of Brick Architecture Through Digital Tools and Technologies

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Abstract

The use of digital tools in the discipline of architecture is becoming more widespread day by day, and it contributes to the strengthening of this relationship between design and production by constantly questioning it. The use of digital technologies and tools has enabled new approaches in the creation of non-standard forms by pushing the boundaries of traditional form and structure understanding. With the increase in the digital thinking skills of designers, there has been a search for new materials and structures, as well as the handling of traditional materials with innovative tectonics. Brick, which is the subject of this article, also appears as a material whose potential is frequently experienced in this process. In this study, the potentials offered by the use of brick through digital design and production tools to the designer are investigated, the "search for original form, search for new structure, relationship with traditional solutions, algorithmic nature of design and manufacturing processes of designs" are discussed with the evaluation on five selected sample projects. In the light of the results obtained, it has been seen that the strong tectonic effect of the brick strengthened the form-structure-material relationship in the digitalization process. Today, it is possible to say that brick is an important and effective material in contemporary architectural practice.

1. INTRODUCTION

Development of digital design and production technologies enables an increasing mutual relationship between technology and design [1]. Current applications of the digital age have become inevitable in the field of architecture. Technologies and tools that have been accelerating in the last two decades are also accelerating the realization of “what we think is possible formally, spatially and physically in architecture” [2]. As the discipline of architecture tries to overcome the fabrication process, as in the construction process, these technologies contribute to the design and production collaboration. Architects re-experiencing many established traditional methods with digital design tools and develop innovative forms, materials, structures and methods and tectonics to combine them. It is predicted that these applications will become indispensable for architecture over time [3].
Today, the form formed in line with the parameters created by the increasing performance demands carries the structure to optimal levels in many ways [4]. Thus, the need for digital design tools in the design and production phase of “high complexity” structures emerging in contemporary architecture also increases [5]. It is important to consider the potentials of the material in the formation of complex geometric forms with digital design tools. Oxman (2010) emphasize the need to explore and understand digital tectonics in order to manipulate the role of material in architecture and the ability to design with materials. The unique tectonics created by the effective geometry of the brick paved the way for the exploration of the potential of the brick material.
Brick has potential to create different forms in building design, as well as being an economical, durable and sustainable building material spread over a wide geography. Throughout the history of architecture, it has been influential in the creation of both structural and aesthetic new forms by affecting tectonics with the compositions it created in the building [6]. The simple geometry of the brick allows for simultaneous

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creation of surfaces of different forms through the increasing complexity of unit-to-unit connections [7]. When brick masonry practices are examined in the history, forms created in this way are frequently encountered. However, creating complex forms from bricks resulted in difficulties in the bricklaying process. Consequently, the complexity of modern freeform architecture has spurred the development of new digital design processes in recent years [8]. While this complex construction process was mostly labor intensive and manual until recently, today digital design tools make a great contribution to the production of non-standard forms in the building [5]. Architects explore innovative manufacturing techniques to create new brick tectonics and an automated construction process through emerging technologies.

While non-standard forms are created thanks to digital design tools, innovative architectural approaches to new materials and structural forms are also developed. These tools not only create new design and construction processes, but also expand architectural thinking and traditional perspectives. In this context, this study, basically, "How is the use of brick material undergoing a change and transformation in the 21st century architecture, where digital design and production tools have begun to dominate?" and "How is brick tectonics evolving in this change?" seeking answers to questions. For this purpose, firstly, how the brick can be used in a computer-aided environment with a more innovative approach has been researched, and 5 projects that have been completed in recent years have been examined in order to contribute to understanding the change/evolution in design and construction technologies and to question the position and potential of brick as a contemporary material in the digitized world. Thus, the effects of changes in design and production technologies have been examined through examples, and the situation of brick as a contemporary material of today have been questioned.

2. LITERATURE REVIEW AND THEORETICAL BACKGROUND

In this section, the place and importance of brick material in architecture is emphasized and the evolution of brick from traditional to contemporary usage is summarized. In the first part of the literature review, the production of brick with traditional methods and the tectonic effects it creates is examined, then the change created by innovative technologies on brick material is evaluated with examples in order to evaluate the transformations created by today's technology.

2.1. Traditional brickmaking and tectonics

The history of brick is based on its use as adobe in Ancient Egyptian and Mesopotamian civilizations. It was originally used in warmer climatic regions. With the developing technology, the production and use of brick in construction continued from the Romans to Europe, and from Europe to the world [9].

The traditional brickmaking system (Fig. 1) is the shaping of moist clay by hand molding and then molded clay is dried in the sun to product the brick unit, as is still in practice in some arid climates [10].

Figure 1. *Sun drying processes of brick [11]*

Firing clay bricks dates back more than 5000 years and has evolved over time into a very sophisticated and highly controlled manufacturing process (Fig. 2). The principle of firing continues to transform clay into a more "stable, durable, and low-maintenance" ceramic material [12]. The first important change in the production of the brick was the firing of the molded brick material in special drying mechanisms instead of using natural methods. While this process gave the brick the durability of stone, it provided more flexibility in creating architectural surfaces [13]. The manufacture of brick material has seen many innovations throughout history; however, the forming process has remained dependent on the molding or extrusion system [14].

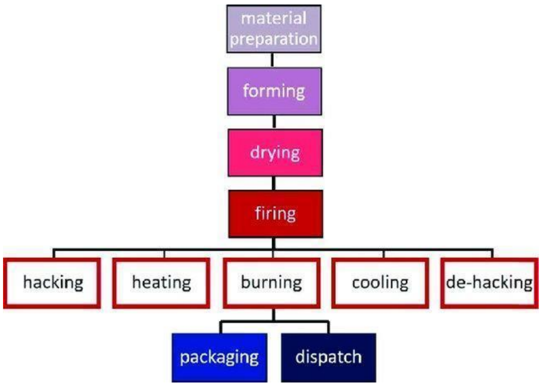

Figure 2. *Brickmaking process [15]*

The production of fire bricks, which are still in use today, gained momentum with the invention of brick making machines in the second half of the 19th century [16]. Industrialization of brick production, has brought important experience to architecture in terms of fast, economical, aesthetic and durable construction of structures such as residential buildings, worker settlements, factories, *etc*. [17]. In the 20th century, with the increase in the need for housing, brick material left its place to steel, concrete and glass for reasons such as durability and economy. Brick has become a material used mostly on surfaces because of its lightness and resistance to fire [18]. Although its popularity decreased in the 19th and 20th centuries, brick material continued to be used structurally by master architects and engineers of that period due to its potentials. For example, as can be seen in Figure 3, the works of masters such as Guastavino and Dieste have entered the literature as labor-intensive and skilled craftsmanship works that require expensive molds [9]. When looking at the brick applications created in this process, structural forms with strong tectonics can be seen easily.

Figure 3. *Central Congregational Church, by Guastavino Company, 1891 (left) [19] Christo Obrero Church, by Eladio Dieste, 1960 (right) [9]*

Late 19th century to late 20th century the use of the brick material in the building by Louis Kahn, Frank Lloyd Wright, Alvar Alto and many other builders proved the aesthetics, versatility and practicality of the brick (Fig. 4) [9]. Traditional construction systems have been influenced by the technology over time.

Figure 4. *Muuratsalo Experimental House, by Alvar Alto, 1952 (left) [20] Ayub Central Hospital, by Louis Kahn 1975 (right) [21]*

As a result, more than a century of industrial developments has made brick material more durable and made the manufacturing process of the brick more efficient. Especially in the 21st century, the use of brick with the developing digital technologies has led to the development of revolutionary approaches to brick in terms of architecture [22]. Contemporary projects show a variety of brick assembly configurations and design solutions, but less development in “basic geometry, brick unit and fabrication methods” [23]. Brick material, which has survived by changing/developing in terms of manufacturing and joining/detailing techniques over time, continues to create building compositions by developing construction techniques / tectonics by architects / designers / stone workers thanks to its advantageous geometry.

2.2. The transformation by digital tools

Over the past three decades, the process of transition to digital has greatly influenced architectural trends. As digital tools can be used to design and manufacture at the same time, CAD/CAM technologies have begun to bridge the gap between business partners and manufacturers [24]. The integration of design and production processes redefines the practice of architecture in terms of both creating new spatial/tectonic qualities and facilitating organization among all users. But the generation or representation of form is not the only concern for today's architecture. The ability of process and manipulate sophisticated forms has led architects to question the possibilities of constructing these complexities. With the help of computational technologies, the geometric constraints imposed by traditional techniques have been overcome and the gap between design and production has been minimized. Thus, it has been seen that it is possible to reform not only the design strategies, but also the entire architectural perception and boundaries [25].

The digital age is emerging with a new type of architecture defined and challenged by emerging new technologies and computational techniques. With the introduction of digital technologies, current understandings in architecture have also changed. Traditional construction techniques, which were used before digital technologies and still continue to be used, tend to create structures with right angles and vertical walls [26]. New technologies in architecture seek to replace and improve traditional techniques, contemporary architectural practice tries to reach the optimal form by using various software programs to create personalized, non-standard and complex forms [1]. Formal precision re-emerging with the development of digital technologies re-evaluates complex curvature geometries, while digital tools for design and fabrication have the ability to reduce technical limitations and make structural surfaces workable again [27]. This potential encourages designers to rethink or examine how they can contribute to updating architectural traditions [28].

Today, while new digital techniques/methods continually expand the expressive and stylistic possibilities of curved shapes, bricklaying should not be limited to traditional tectonics [29]. For this reason, existing methods used in the design process for brick materials and bricklaying methods, as in other building materials and tectonics, have begun to be reviewed and developed with the opportunities offered by digital tools. Research continues to understand the potential of the brick in the automation-intensive construction process.

3. METHOD

In the past, especially from the 20th century, the use of brick by some builders has shown the unique tectonic effects of brick and has led to the realization of the potential of brick on today's projects. The form-material-structure relationship brought about by the tectonic effect created by the brick material is tried to be developed with today's technology, especially by overcoming the workmanship process.

In order to evaluate the changes created by the digital tools on the brick material, an evaluation was made through the parameters determined on the case studies completed in recent years. In the light of the data obtained from the literature review, the evaluation parameters were reached. In order to see the effect of these parameters on brick architecture, 5 projects constructed with the integration of brick and digital tools in recent years were selected and the change/transformation created by digital tools on brick material was analyzed.

The parameters determined to examine the non-standard applications of the brick with the use of technological tools today; search for original form, search for new structure, relationship with traditional solutions, algorithmic nature and manufacturing process.

3.1. The search for original form

Throughout the history of architecture, architects have been in search of original forms in order to achieve more durable, economic and aesthetic effects. Especially since the beginning of the 20th century, building designers have been in search of original forms in order to benefit from the structural solutions created by the form, in the light of developing technologies, and they have tried to benefit the building with innovative forms. As a result, in this article, the search for the original form will be evaluated according to the benefit of the produced form to the structure.

3.2. The search for a new structure

Structure is the skeleton system formed by load-bearing systems and elements. According to Picon's (2003) definition, structure is the one that makes it possible to come together structural elements. Techniques specialized in the direction of technology and developments in geometry have had a great impact on architects in their designs, such as calculations and performance analyzes of architectural structures. The transformations brought about by the continuous processes created by the use of digital tools in the formation of the structure, in relation to the formation of the structural installation, encourages the search for new structures in today's studies [30]. Evaluation of the selected samples in terms of structure appears as an important evaluation parameter in this integrated process.

3.3. Relationship with traditional solutions

It is important to benefit from traditional construction solutions in the new solution processes. In particular, at the point where today's technology has come, algorithmic software systems are beneficial in creating new construction methodologies by taking advantage of this spectrum. In this article, relationship with traditional solutions will be evaluated through selected examples to understand its contribution to new manufacturing techniques in this process.

3.4. Algorithmic nature of design

Algorithm is a set of mathematical rules used in architectural design in the pre-computer period [31]. According to Caetano (2016), an algorithm can be defined as a set of rules that define a set of operations required to perform a task. Today, architectural solutions are interpreted and realized computationally, with the crucial help of modern computers, and make use of algorithms. The major contribution of the algorithm to architecture today is that it is a controllable and easily manageable design approach that allows the production of several different variations of the design. Through selected examples, the role of the algorithmic nature of design in design will be questioned.

3.5. Manufacturing processes

Manufacturing processes are of great importance in design in terms of the benefit they provide to the physical creation of the design through software and production tools. The use of digital tools in the architectural design and construction process guides the relationship between form and structure in digital tectonics by using various strategies of the structural engineer [33]. In this article, the effect of the technological developments in the production processes on the architectural building construction processes is considered as an important evaluation parameter and the contribution of the technologies used in the manufacturing processes will be examined through selected examples.

4. ANALYSIS OF SELECTED SAMPLES

The field study section of the article, the parameters given above were analyzed with the selected samples. Winery Gantenbein, Brick-Topia, Vertical Village, Clay Rotunda and Ceramic InFormation Pavilion were selected as examples where digital technologies were integrated with brick material, and the possibilities offered to the designer in the light of the obtained parameters were examined.

4.1. Winery Gantenbein / Gramazio & Kohler

Winery Gantenbein (Fig. 5) is an industrial winery built in 2006 by Gramazio and Kohler in collaboration with Bearth & Deplazes Architekten firm. While creating the building, spatial solutions were produced considering the purpose of use of the building and these solutions were tried to be reflected in the architectural language. In order to do this, a brick facade configuration was designed using digital tools and parts of the facade were created with robotic assembly processes.

Figure 5. *Winery Gantenbein by Gramazio & Kohler interior [34]*

Searching for original form: Winery Gantenbein project is a project in which reinforced concrete structure and bricklaying techniques are used together. While creating the project, brick material was used to “create an original form”. Thanks to this unique form, the right room climate and natural ventilation are provided to the building. The originality of the structure, whose design was created thanks to digital technologies, was achieved by transforming the production technique of the produced product(wine) into a digital image through the simulation techniques and then creating different angles in the arrangement of the bricks with the image created with digital tools (Fig. 6).

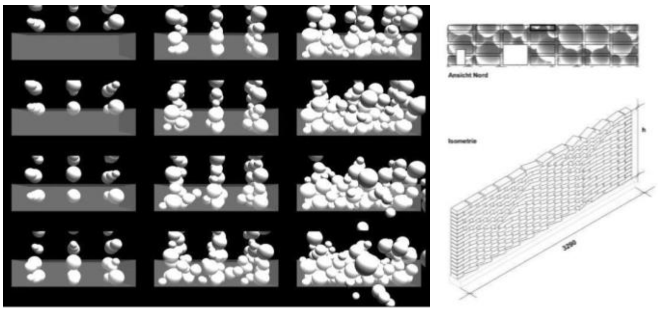

Figure 6. *Winery Gantenbein facade design process [35]*

Searching for new structure: The building structurally benefited from the flow of classical masonry bricklaying techniques, but the main structure was obtained with a reinforced concrete skeleton and the brick part served as a filling function. For this reason, no new "structure search" was observed in this building design.

Relationship with traditional solutions: While creating the Winery Gantenbein project, it is based on the system of joining brick units by means of mortar, as in the "traditional brick construction". However, the high number of bricks and the desire to assemble in a short time led to the use of robotic technologies in the construction process. Thus, the robot arm created a more complex brick pattern in a short time, imitating the traditional bricklaying process.

Algorithmic nature of the design: This industrial building design was transferred to the robotic language directly by reflecting the visual created through simulation in the computer environment, the created facade was directly transferred to the robotic language, and the existing manual process was imitated with robotic technology without the need for an extra drawing and without any manual processes. The transmitted information was mapped to the wall, allowing each brick to be rotated around its center point. This allows creating an algorithmic pattern as well as mapping the images to the wall [36]. The angles of the bricks provided different light reflections to the building and the need of the building was met thanks to the pattern provided by the produced algorithm.

Manufacturing processes: First of all, the project was designed as a concrete skeleton structure and it was aimed to meet the building needs by filling the inside of the skeleton through a brick wall. With the robotic production method, the bricks were placed according to the desired angle with the visual created by the simulation of the wine production technique (Fig. 7) [35]. In this way, the façade has been brought to meet the needs of the building. The generated data was used by the robot to assemble the brick module one by one, as a traditional bricklayer would do [36].

Figure 7. *Manufacturing process of Winery Gantenbein [35]*

4.2. Brick-Topia / Paula Lopez Barba & Josep Brazo Ramirez

Brick-topia (Fig. 8) is a multifunctional catalan vault structure for events. Brick-Topia's design process is based on a combination of traditional and efficient construction techniques and digital technologies (structural analysis and form finding). Brick-topia is the first free-form, human-scale vault structure made of brick at such a scale.

Figure 8. *Brick-topia by Manual de Lozar and Lopez Barba [37]*

Searching for original form: The Brick-topia project is generally a project with a vault form produced with the Catalan vault technique. The situation that makes the form of this project unique is that the form was created with the help of digital tools, and the form was formed with the solution that provides the static benefit.

Searching for new structure: With the help of technologies, the structural behavior of the building was tested and the optimal structure was reached through form. Thus, despite the use of ceramic tiles as a material and the Catalan vault technique, which is an old technique, as a construction technique, an innovative structure was obtained thanks to the structural analysis provided by digital tools [38].

Relation to traditional solutions: Brick-Topia is a vaulted structure made of brick using a traditional construction technique called thin tile vaulting, and it interacts deeply with traditional solutions. The project reveals the validity of the traditional construction technique in contemporary applications. Traditional handmade bricks were used in the building and care was taken to use these bricks in the size of the brick type called thin brick.

Algorithmic nature of the design: With the newly developed RhinoVault, form-finding algorithms (Fig. 9) were used in the form creation phase. However, the brick-and-mortar masonry stage was carried out manually, and the work was facilitated by the waffle system created with digital technologies and the scaffolding created by reinforcing bars [37].

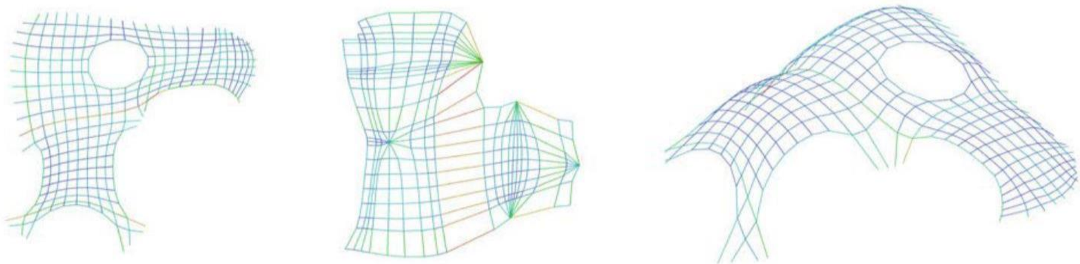

Figure 9. *Form Finding with RhinoVault [38]*

Manufacturing processes: In order to obtain the complex form created with RhinoVault during the production process, the need for a mold arose, and for this, a waffle system (Fig. 10) was created with the help of CNC machines. The production of the form, which was created with the help of the traditional thin ceramic vault system and digital technologies, was carried out manually in the construction area [38].

Figure 10. *Construction process of the Catalan vault [37]*

4.3. Clay Rotunda / Gramazio & Kohler

Clay Rotunda project is a sustainable music auditorium structure in organic form, created with clay material by Gramazio & Kohler, who have made a name for themselves with their work in this field. Calculations of the design were provided by individual engineers and the potential of the brick was successfully exploited. Thus, the necessary acoustics for the music auditorium were provided through the material [39] (Fig. 11).

Figure 11. *Clay Rotunda by Gramazio & Kohler [39]*

Searching for original form: The original form of the building was created in a wavy form thanks to calculations made in the computer environment. Thanks to this form, the shell has successfully provided optimal benefit.

Searching for a new structure: The Clay Rotunda is a free-standing earth-based cylindrical structure. The wavy structure of the shell form of the structure provides thinness to the shell, which stabilizes the structure and prevents buckling. Thanks to the calculated pressure provided by the robotic arm, the structure was interlocked, creating a successful new structure.

Relation to traditional solutions: Robotic clay picking combines traditional knowledge of clay structures with contemporary digital design and fabrication processes. The building took advantage of traditional brick making processes, and with the help of digital tools, a clay structure was obtained without the molding process.

The algorithmic nature of the design: The structure was created by digital technologies and its form was determined by the calculations. In this computational process, algorithms are created to determine the position of the units and the order of construction within the segment. In this way, the units were clamped together by providing the relationship between the different segments with the angle created according to the pressure direction determined on each unit by means of the robotic arm [39].

Manufacturing processes: The Clay Rotunda was built in situ by a precisely guided clay brick-forming robotic system as shown in the figures (Fig. 12). The clay was collected and shaped by the robot and then precisely placed one by one by the robot.

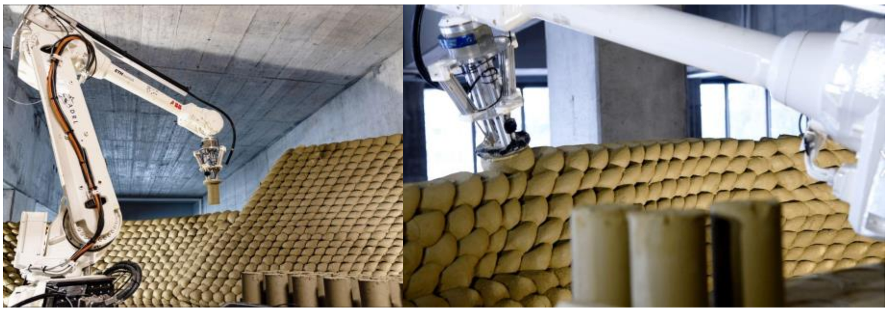

Figure 12. *Manufacturing process of Clay Rotunda [39]*

4.4. The Vertical Village / Gramazio & Kohler

Vertical Village project is the prototype of a utopia project in 2011, which is the first example of assembly (flight-assembly) production technique using some kind of drone mechanism (Fig. 13). The most important feature of the structure, which is made of polystyrene blocks, is that the production process was carried out by quadrocopters.

Figure 13. *Vertical Village Project by Gramazio & Kohler [40]*

The search for original form: The project has a void designed form with 60 different layers overlapping each other vertically. Thanks to digital tools, the optimization of the form was calculated and thus it was possible to produce the project with polystyrene bricks in a complex form.

The search for a new structure: With the Vertical Village project, the complexity of the structure, as well as the form, is shaped by digital technologies and the production process (ARC) used and has the potential to pave the way for large-scale structures in architectural design.

Relationship with traditional solutions: The technologies used in this project try to replace the traditional method. The project takes a completely robotic approach rather than a manual process.

Algorithmic nature of the design: In the Vertical Village project, a structure’s envelope was created with a customized algorithm, taking into account gravity and tolerance calculations. Computational optimization process, as in the below (Fig. 14), optimizing the geometrical condition of structure such as the curve radius and curve length, and checking for overlapping areas [40].

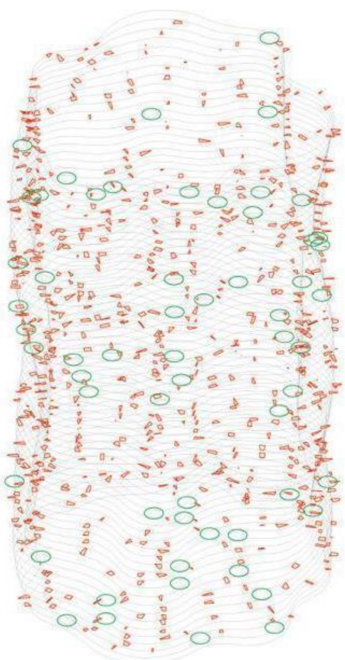

Figure 14. *Optimization of curve radius and curve length, also overlapping areas [40]*

Manufacturing processes: In the manufacturing process of this project, 1500 polystyrene bricks determined the flight behavior of the quadrocopters thanks to the generated data, and brick flow was ensured by assigning each unit to the determined position by Aerial Robotic Construction (ARC) and the assembly process is complete. Thus, the system became a pilot project to get rid of the constraints of traditional solutions.

4.5. The Ceramic InFormation Pavillion / Lange & Holohan

Ceramic InFormation Pavillion is a structure designed by Lange & Holohan in 2017, using the potential offered by today's computing and manufacturing tools to develop a system that can rely on its own structural material capacity (Fig. 15). Thanks to the specially designed ceramic units, the pavilion has become an example that successfully demonstrates the potential of brick material.

Figure 15. *Ceramic InFormation Pavillion by Lange & Holohan [41]*

Searching for original form: A special smart brick was developed using robotic controlled ceramic 3d printer technologies in order to obtain curved form in Ceramic information pavilion. According to Lange (2019), if normal brick units were used instead of the smart brick system it has in the project, the complex surface it has would not be able to reach easily. A unique form has emerged by combining and positioning special units.

Searching for new structure: The building has a self-supporting structure system of special brick units produced via 3d printing. Thanks to the interlocking structure, the proposed system does not require an additional organizational structure.

Relationship with traditional solutions: While designing the Ceramic Information pavilion, brick material was produced as in traditional brick production techniques, and the unit was reached by using new systems instead of the mold process, but the extrusion system was adhered to. Considering the shrinkage of the brick after the firing process, the units were created in a scaled manner in the computer environment. Finally, the bricklaying process was created and developed with the traditional brick flow in mind.

Algorithmic nature of design: Parametric design approach was used while creating the project. For the configuration of the brick unit whose geometry changes gradually, an algorithm is created in which the relationship of each brick with the neighboring units is observed. Thus, the assembly process was also designed digitally [41].

Manufacturing processes: This pavilion structure has customized the brick unit (Fig. 16) using the 3d printing method one of the additive manufacturing (AM) methods in digital production. Thus, an intelligent brick jointing system was created and a special mounting system was developed for positioning. The smart brick system, which was produced in line with the calculations, allowed the assembly of the building by people who are not skilled in this field during the assembly process.

Figure 16. *Units of Project [41]*

5. EVALUATION AND CONCLUSION

Brick has been used for building innumerable structures over thousands of years due to the fact that it has many advantages. Throughout the history of architecture, brick architecture has shown its potential, especially with its applications in the 20th century, but due to the difficulties in the implementation of the tectonic effect it has created, it has been replaced by materials such as steel and concrete for a long time. With the elimination of these difficulties by today's technology, brick has come to the fore again and it has again gained the opportunity to reveal its advantageous sides compared to other construction materials. Today, brick emerges as a material that should be evaluated under today's conditions due to its properties. This study shows that brick is still an important and effective material for architectural practice even today because of its proven tectonic and economic advantages. In this paper the "search for original form, search for new structure, relationship with traditional solutions, algorithmic nature of design and manufacturing processes of designs" are discussed with the evaluation on five selected sample projects which are Winery Gantenbein, Brick-Topia, Vertical Village, Clay Rotunda and Ceramic InFormation Pavilion. These projects are important projects that show the possibilities of designing with bricks through developing technologies and thus pave the way for developing the advantageous aspects of brick.

In general, the results obtained from Table 1 show that the change created by digital tools strengthens the form-structure-material relationship in architecture by affecting today's architectural design and application processes. The effect of the algorithms created in the computational environment together with the various tools used in the production processes on the design shows that it affects the tectonic traditions through the selected case studies. The selected projects have been successfully designed under the influence of the determined algorithms. In some projects, these algorithms were also used in the production process. Thus, it has been observed that the changes in the architectural approach from the architect/engineer brick material have a great effect on creating the original form. These changes also show the existence of a new structural search with brick, but it is understood that the material is not always used in a structural sense. As seen in the table, traditional solutions have had a significant impact on the realization of today's design, but it has been observed that a new option is needed in some projects.

Table 1. *Evaluation of the case studies (AM: additive manufacturing, ARC: quadrocopters)*

Sample Structure	Sample Structure Images	Searching for Orginal Form	Searching for New Structures	Relationship with traditional solutions	Algorithmic Nature of Design	Manufacturing process
Winery Gantenbein		Form is created due to provide space's needs through the material-driven architecture	The digital tools provide perforated effect on masonry wall and design flow of forces	Traditional masonry wall techniques was improved	The rotating effects of bricks was provided from image and transmitted into robotic language	Robotic Arm 
Brick Topia		Form is the result of structural setup, it has force-defined geometry	Structure is the result of manipulation of boundary conditions	Traditional catalan vault technique was experienced	RhinoVault optimised the structural setup of form	Manual 
Clay Rotunda		Suitable nature of material in fabrication, provides creation of undulating and slender form	Structure shows the opportunities of architectural shapes for creating structural logic	Standard clay material manufacturing techniques was used as a knowledge	Through the algorithm, position of unit decided and direction of pressure of robotic arm made possible the join of each unit	CNC, Robotic Arm 
Vertical Village		Form is created thanks to efficient use of material to achive higher degree of complexity	Logic of stacking material has an effect on structural system and the way of transferring loads	Project aims to replace traditional techniques stricting sides and provide more advanced solutions	Customized algorithm of vertical village provided convex envelope, with gravity and tolerance calculations	ARC 
Ceramic InFormation Pavillion		Form is the result of structural logic that provides higher degree of complexity	The structural system is developed in an evolutionary process that provided flow of unit-neighbour unit	Standard clay material manufacturing techniques was used as a knowledge	Each unit's relationship with the neighbouring units decided by algorithm	AM 

The fact that the brick material is a suitable material for today's technology and that complex forms can be easily created in this way turns the brick material into a promising material for the future. The selected projects aimed to improve the brick material, and while doing this, the techniques and knowledge applied in the past projects were used in this process. In particular, the structural effects of complex projects on the building and the benefit of today's technology in the formation of complex surfaces reveal the importance of designing with brick material for today and the future. To sum up, existing technologies have an advantageous impact on building production and therefore these technologies have prompted architects to rethink the impact of material. In this study, the development and use of brick material is discussed in order to see the effects in question. When past and present examples are examined, brick improves its disadvantageous aspects by gaining resistance through form in the building, thus making it more possible to benefit from its advantageous aspects. Today's technology facilitates the formation of these complex forms and enables the potential of brick material to be evaluated. The search for original form, the search for innovative structures, its relationship with traditional solutions, the algorithmic nature of design, and the examples evaluated in the context of manufacturing processes, the transformation created by the digital tools used today are evaluated through the brick material. The paradigm shift created by digital tools in architecture has enabled successful use of the traditional tectonic effect of brick in innovative architectural projects today. Along with technologies inspired by traditional design processes, brick has brought optimal benefits to the building by creating innovative forms thanks to its strong tectonic effect in building design. Thus, the material has revealed its potential in projects both structurally and aesthetically. In the light of the data obtained, the integration of brick manufacturing processes and today's technology has shown that brick is a suitable material to be a contemporary material. As a result, it has been observed that brick material, which has been frequently used as a facade cladding material since the 20th century, is a material with significant potential by creating new opportunities, which should be reconsidered in the architectural discourse through the opportunities created by innovative techniques.

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