Neobrick: Environmentally Informed 3D-Printed Lattice Brick for Modulating Indoor Thermal Comfort

47

Ji Yoon Bae and Jenny Sabin

Abstract

NeoBrick is a 3D clay-printed brick prototype that explores generative design processes coupled with environmental inputs as design drivers. Maintaining indoor thermal comfort by utilizing a passive cooling strategy contributes to energy efficiency and healthy indoor air environment in a specific climatic context such as tropical climate zones. In this aspect, clay is a locally accessible material that brings thermal benefits for cooling due to the low heat conductivity. Moreover, environmental simulations and additive manufacturing techniques are emerging as key drivers for designing and testing a performance-driven architectural systems. This paper introduces an integrated research workflow that develops a Triply Periodic Minimal Surface (TPMS)-informed clay-printed brick system. The brick geometries are informed by environmental feedback including airflow and heat transfer performance. To articulate this environmentally performing clay brick prototype, first, this research leverages computational fluid dynamics (CFD) and heat transfer analysis to inform and evaluate brick geometries. Second, the research utilizes an additive manufacturing technology with customized toolpaths for fabricating non-standard brick geometries. Lastly, the research delivers a possible residential architectural application in a specific climate condition, Ho Chi Minh City, Vietnam, to suggest a possible adaptation of the passive ventilation system for enhancing the thermal environment and energy efficiency.

Keywords

Performance-driven design · Parametric clay brick · Clay 3D printing · Ceramics · Periodic minimal surface · Computational fluid dynamics

47.1 Introduction

47.1.1 Climate-Responsive Architecture

Recently, building energy consumption has stimulated concerns about the risk of climate change and depletion of energy sources (Susanne et al. 2014). To cope with this socio-climatic issue, climate-adapted building systems can play key roles in satisfying modern living standards. Historically, vernacular architecture has demonstrated material systems and optimization processes to obtain comfortable built environments

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in local climates (Salman 2019). The primary objective of traditional passive cooling systems is to bring indoor thermal comfort by controlling daylight and ventilation in combination with other domestic factors such as privacy and local aesthetics. One example of a vernacular cooling system is *Mashrabiya*, which is a famous traditional window screen in the Middle East. The shape language of this screen responds to the local socio-climate condition, Islamic culture and hot desert climate. *Mashrabiya* performs functions including defusing light, allowing airflow, and protecting privacy. These functionalities enable users to achieve the thermal comfort by passively ventilating indoor spaces (El Semary et al. 2017).

Architects are now exploring computational tools and simulations across project scales to understand thermal comfort and energy efficiency (Peters and Peters 2018). This paper builds upon studies that focus on maintaining indoor thermal comfort through a performance-driven design process by utilizing environmental simulations and digital fabrication techniques. Thus, the research starts with the question: How might an environmentally informed parametric ceramic brick system maintain thermal comfort?

The research aims to develop an environmentally performing architectural component using clay material. Environmental simulation and additive manufacturing are utilized to inform and fabricate non-standard brick geometries. This brick prototype is expected to maintain indoor thermal comfort by allowing natural ventilation and filtering direct solar radiation.

47.1.2 Ho Chi Minh City, Vietnam

To demonstrate possible architectural applications of this research investigation, it is critical to integrate geographical constraints that include local socio-climatic contexts. To this point, the research focuses on Ho Chi Minh City, which is in the southern part of Vietnam. This city is one of Vietnam's most populated metropolitan areas. The region features a tropical climate zone with sweltering weather. This condition remains constant throughout the day due to the high humidity level.

Tube house is the most common dwelling typology in the city. These traditional houses were built before and after the French colonial era. The Vietnamese economic reform in 1986 made a significant shift in their dwelling typologies (Anh et al. 2016). Today's tube house is typically 4 m wide, more than three times in depth, and vertically stacked with multiple floors (Kien 2008). Originally, tube houses had open courtyards or glass ceilings within buildings to improve natural ventilation. However, once the HVAC system was adopted throughout the city, the open courtyard became an indoor space, and the glass ceiling fell out of use. The main issue of today's tube houses is that residents do not operate mechanical cooling systems because of the high cost of utility fees. In 2018, only 17% of Vietnamese households owned air conditioners (Minh 2018). Also, this building typology rarely has semi-open spaces because many of them sit together to form a continuous building block.

The current tube houses create tight spaces around their living spaces, resulting in a few openings that allow small amounts of wind and natural light. Therefore, today's tube houses are no longer adaptive to the local climate conditions. Tube houses have the physical look of Vietnamese vernacular architecture but have abandoned their climate-adapted features (Anh et al. 2016).

With the above considerations surrounding vernacular architectures with energy efficiency and climate context in mind, this project aims to achieve the following objectives: (1) investigate 3D-printed ceramics as a primary construction material, which is accessible in a wide range of locations and has potential thermal benefits; (2) develop the environmentally informed non-standard brick geometry to modulate environmental factors such as airflow and heat transfer; (3) additively manufacture using customized toolpathing to articulate the performance-driven complex geometries of the brick prototype; (4) utilize computational evaluation tools and techniques to validate the environmental performance of the brick system; (5) propose a possible

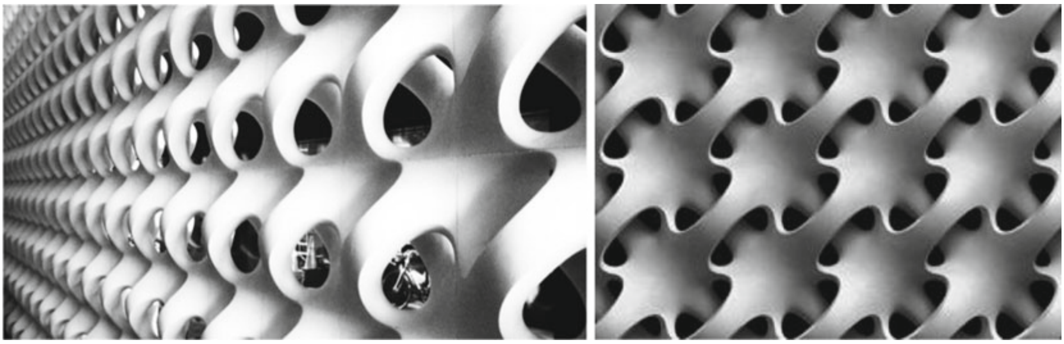

Fig. 47.1 Erwin Hauer's lattice screen (Credit: Erwin Hauer)

architectural application of the perforated brick system in a particular region, Ho Chi Minh City, Vietnam, where the brick system can be applied in response to a local climate condition. This architectural application highlights impacts of the brick that potentially reduce the cost of living for mechanical cooling while enhancing the quality of indoor environment.

47.1.3 Non-standard Geometry and Emerging Technology

In modern architecture, lattice-structured screens with complex geometries emerged and were used as either building façades or indoor screens. Erwin Hauer, an early proponent of modular constructivism, designed light defusing lattice screens. The geometry of these screens was artificially modulated by using algebraic equations (Hauer 2004). The concept of the screen system is to create a pleasant indoor environment by diffusing the natural light (Fig. 47.1).

Now, emerging technologies enable designers to explore more integrated pipelines informed by expanded environmental parameters. Additive manufacturing is an innovative technology that enables designers to redefine brick geometries. *Polybrick 1.0* is one of early brick prototypes using additive manufacturing to fabricate complex brick geometries (Fig. 47.2: Left). This non-standard mortar less brick has opened possibilities of brick as a sustainable construction material informed by a variety of design parameters (Sabin et al. 2014). *Ceramic Morphologies* is a project that designed and 3D-printed an industry-scale ceramic building component (Fig. 47.2: Right). The ceramic 3D printer allows designers to produce mass-customized brick geometries (Seibold et al. 2018).

These projects illustrate the potential of clay additive manufacturing for the mass-customized building components. However, interdisciplinary studies between 3D ceramic printing technology and environmental performance-driven design have not yet been deeply explored. To optimize and examine the environmental performance of design outcomes, computational environmental simulations become a key process that informs and validates design iterations.

47.1.4 Environmental Factors as Design Parameters

Building performance simulations and 3D fabrication techniques are primary design drivers that enable the development of environmentally performing building components. Therefore, researchers have been exploring design workflows that link environmental simulations to design practices. The implementation of environmental feedback in the design process is a key methodology supporting design decision-making (Chronis et al. 2017). The study, *Integration of CFD in Computational Design*, utilizes computational fluid dynamics (CFD) to provide

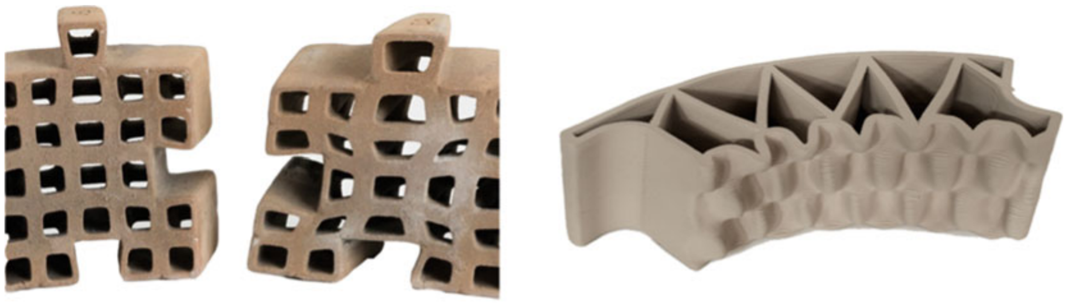

Fig. 47.2 3D-printed clay bricks. Left: polybrick 1.0 (Sabin et al. 2014). Right: ceramic morphologies (Seibold et al. 2018)

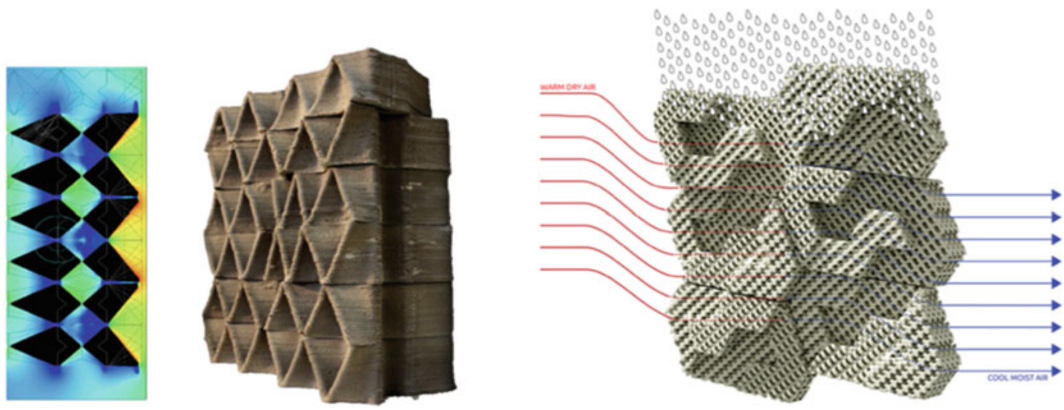

Fig. 47.3 Environmentally informed architectural components. Left: integration of CFD in computational design (Chronis et al. 2017). Right: cool brick (Emerging Object 2015)

designers with design feedback on 3D-printed clay wall geometries (Fig. 47.3: Left). It introduces a performance-driven design pipeline that uses airflow as a design parameter (Chronis et al. 2017). Another study, *Cool Brick*, highlights the environmental performance of non-standard 3D-printed porous brick. (Fig. 47.3: Right). This brick cools when the air passes through pores of the wet brick surface due to the evaporative cooling mechanism (Emerging Object 2015). It demonstrates the possible adaption of perforated brick as an alternative architectural component for energy-saving strategies. However, both studies address limitations of the validation process of environmental performance. Moreover, the performance was evaluated with the final iteration and the simulation tools were not used closely throughout the entire design process.

47.2 Method

47.2.1 Research Framework

The research pipeline synthesizes two research trajectories, additive manufacturing and environmental simulation, to develop and test the environmentally informed parametric brick system. The project follows four research phases (Fig. 47.4).

First, (1) the research explores triply periodic minimal surface (TPMS) as brick geometries. In this phase, the research investigates different types of TPMS structures often used as heat exchangers in engineering research. The primary TPMS form, *Neovius*, is chosen based on the conjugate heat transfer analysis results. (2) The

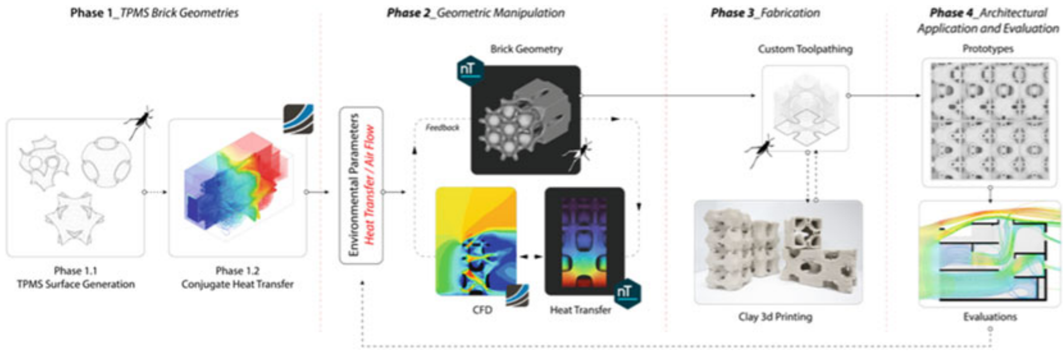

Fig. 47.4 Overall research pipeline and computational tool proxies

second phase focuses on generating tailored porous brick geometries by manipulating pore properties such as size and opening direction. Then, different brick prototypes are computationally tested to see how the geometric properties influence the airflow. (3) To fabricate the environmental performance-driven brick geometries, the research utilizes an additive manufacturing approach with the toolpath customization. (4) Lastly, the paper delivers the possible architectural application of *NeoBrick* as a brick façade system employed in a specific climatic condition.

47.2.2 Geometric Manipulation

47.2.2.1 Triply Periodic Minimal Surface

The thermal exchange performance of highly porous ceramic structures has been validated in a wide range of applications such as aerospace engineering, electronic cooling, or solar receivers (Cheng et al. 2021). In particular, triply periodic minimal surface (TPMS) is a mathematically well-known porous structure. Moreover, due to its continuous geometric properties, TPMS can be used to generate multifunctional materials for diverse engineering applications (Abueidda et al. 2017). Therefore, this research features the geometric properties of TPMS structure and leverages its thermal performance as a heat exchanger to develop TPMS structure-informed thermal modulating brick geometries. Three different TPMS structure units, *Schwartz P, Gyroid,* and *Neovius*, are modeled and tested to compare performances relative to heat convection based on different geometric characteristics.

Conjugate heat transfer analysis is conducted with three types of TPMS input geometries using the environmental analysis platform, Simscale (Simscale GmbH 2013) Each geometry has the same size, which fits an air chamber. Fired ceramic brick is assigned as a brick material. Also, the boundary condition is set to 2 m/s, and 67.1°F of inlet air from the Y direction. The TPMS geometries and chamber set to a bit lower, 50°F, than the inlet air temperature (Fig. 47.5). The main goal of this analysis is to compare the heat convection of TPMS structures depending on their geometric shapes.

Based on the simulation results, the surface area of each TPMS structure is calculated. Moreover, the thermal convection of each geometry surface and the air temperature at each outlet are evaluated. *Neovius* has a larger surface area per unit and lower heat convection than the other two TPMS structures. In addition, the air that comes from *Neovius* units has the lowest outlet temperature, 60°F, at 60 s of simulation time steps (Fig. 47.6: Top).

The time–temperature graphs show how long the geometry preserves its original surface temperature when hot air passes pores. In the case of *Schwartz P*, it starts to lose its initial surface temperature at 20 s and reaches 67°F in 180 s. On the other hand, *Neovius* preserves its original

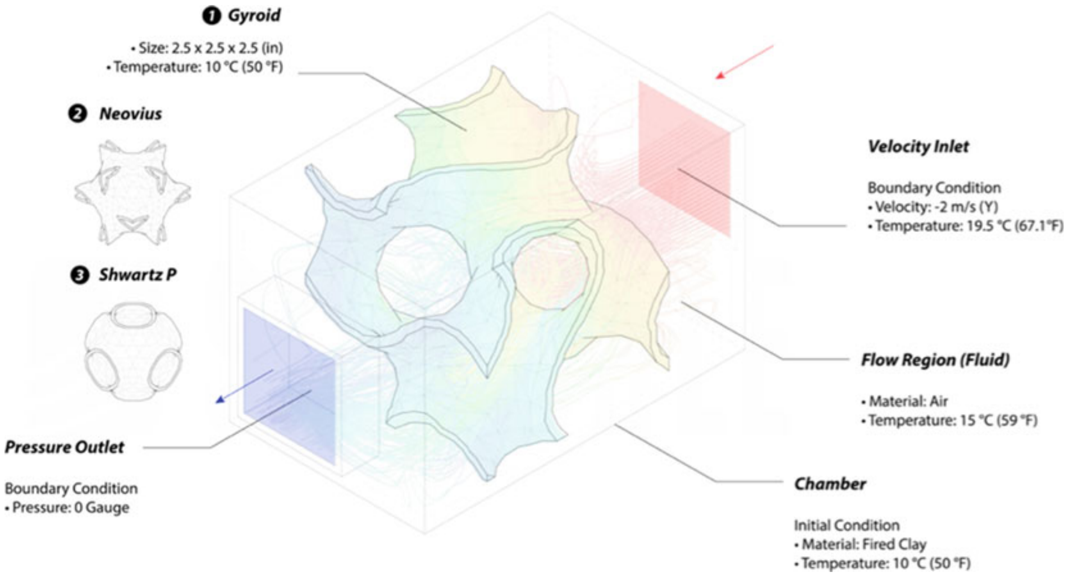

Fig. 47.5 Setting for conjugate heat transfer analysis using different types of TPMS geometries

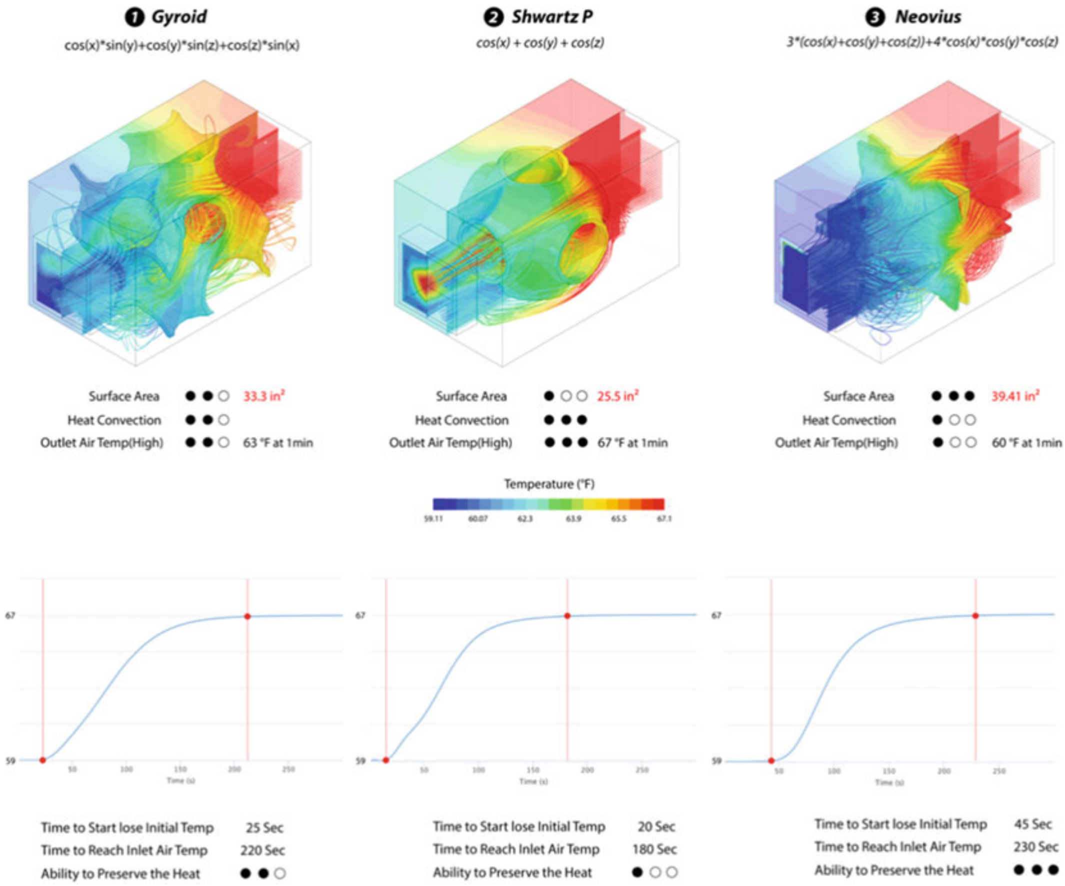

Fig. 47.6 Conjugate heat transfer analysis of TPMS structures (Top) and evaluations (Bottom)

surface temperature longer than other input geometries. It takes 45 s to lose its original temperature and 230 s to reach 67°F (Fig. 47.6: Bottom). Even though *Neovius* allows a relatively small amount of air to be penetrated due to its small pore sizes, it shows potential thermal benefits from its low heat convection. Therefore, this research further investigates *Neovius* as a primary geometry to manipulate its characteristics to optimize the environmental performance.

47.2.2.2 Tailored Brick Surface

One of the main objectives of the research is to develop a perforated brick prototype that controls the direction and amount of penetrated air. Utilizing *Neovius* as a key geometry, this research phase mostly focuses on manipulating geometric properties. *nTopology*, a geometry creation tool for engineers and designers, is used to manipulate brick geometries (Rothenberg 2015). The tool is highly optimized for creating TPMS lattice structures and managing mesh quality. This computational platform enables us to efficiently model complex geometries with different pore characteristics informed by the *Neovius* structure. Several geometric manipulation protocols follow. Two geometries with different pore profiles are subtracted or mixed to generate idiosyncratic moments of transition between pores (Fig. 47.7).

The following CFD results of initial brick prototypes show how the air flows through the

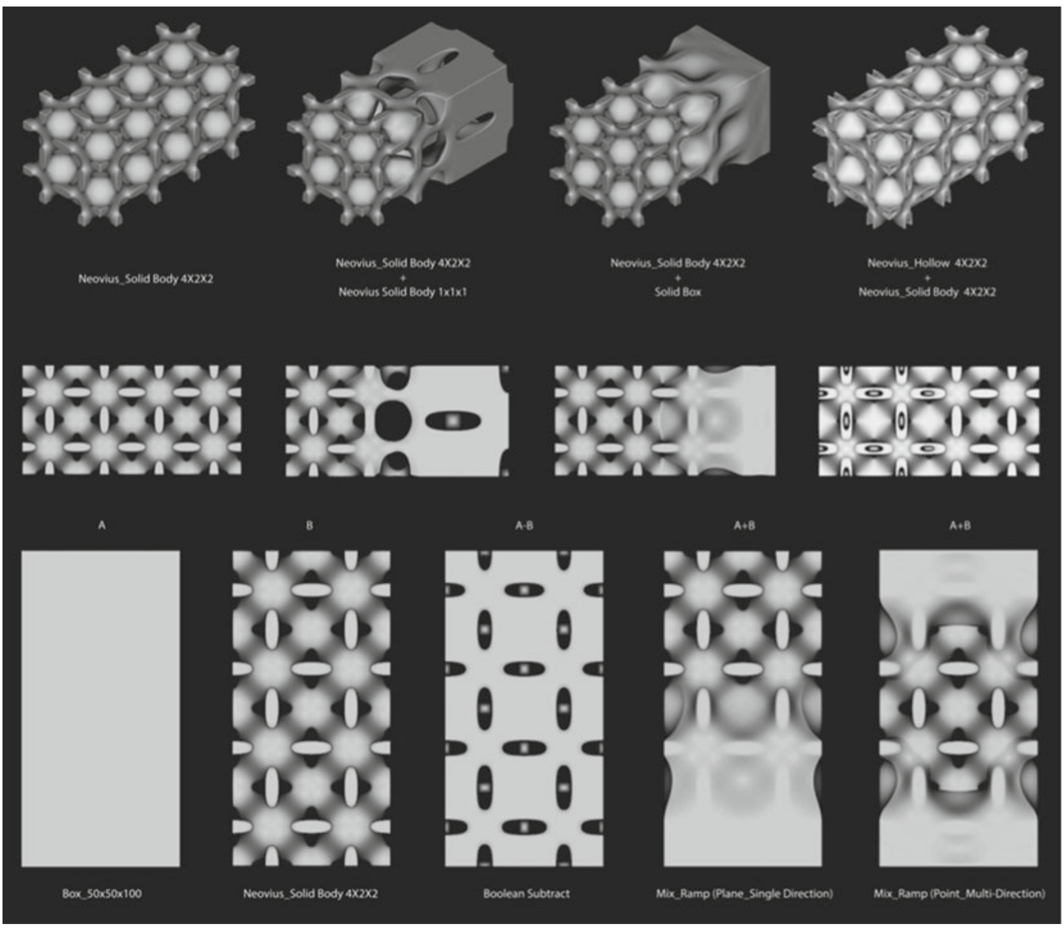

Fig. 47.7 Geometric manipulation of Neovius-informed brick prototypes

brick geometries at certain cross sections. Three different pore sizes, including small, large, and mixed, are implanted to each prototype. Next, the air change per hour for each iteration is calculated to compare its potential natural ventilation (NV) performance as a passive ventilation system. This evaluation process informed how pore sizes of brick geometries affect the airflow. Larger pores and void volume within geometries give more space for air to be passed, which potentially facilitates the NV of indoor spaces working as thermal control perforated bricks (Fig. 47.8). However, the current brick prototypes consequently make the brick units consume a significant amount of clay material and make it heavier while fabricating it. Also, it takes longer to fabricate due to its infill toolpath that it requires for the structural stability. This paper will illustrate these considerations regarding the fabrication process in the later section to discuss 3D manufacturing strategies.

47.2.3 NeoBrick

47.2.3.1 Air Modulating Lattice Brick Prototype

Based on the findings from the previous investigations, this research stage develops the second set of *NeoBrick* prototypes. This phase focuses on optimizing the wall thickness of the brick surface and manipulating the angle and size of inner geometry for modulating amounts and directions of airflow. The new brick geometry is comprised of a rectangular outer shell with 6″ width and 12″ height. The brick includes a thickened *Neovius*-informed wall surface within the outer shell. The rectangular outer shell brings

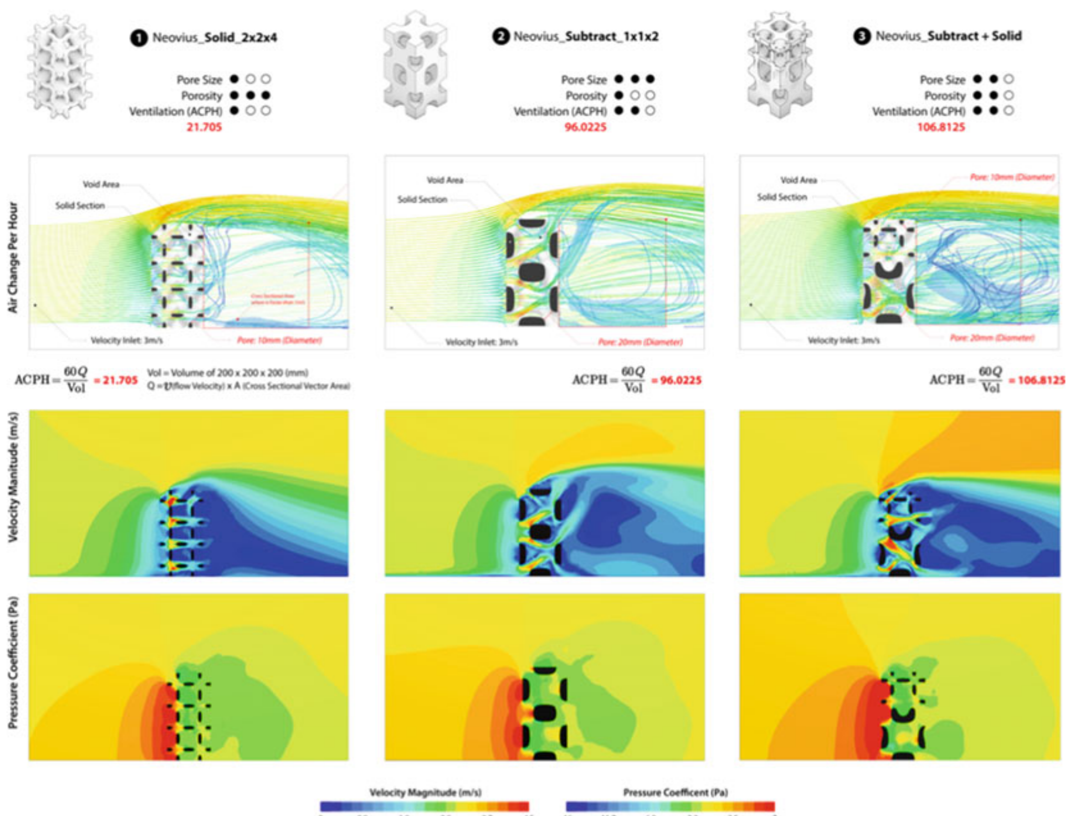

Fig. 47.8 Performance evaluation of brick prototypes with different pore properties

better structural stability and uniformity as a composite brick system. Also, the thickened *Neovius* inner surface creates a larger void volume and enlarged surface area than the solid *Neovius* geometries. Because of the geometric continuity of the TPMS structure, this prototype has idiosyncratic vertical and horizontal sections with different pore profiles (Fig. 47.9).

The critical question here is: How might we control the amount and direction of air from this geometry? The performance of air modulation can be achieved by manipulating the opening property of inner geometries. Therefore, this research developed twelve geometries with three different pore sizes and four different angles of inner geometry. There are two different opening sizes, small and large. Also, the middle prototype between small and large pore-sized brick generates a gradient transition in pore size from small to large. And each inner geometry is rotated every 5 degrees from 5 to 15° in parallel to create different directions of air outlet channels (Fig. 47.10). The size of pores can be controlled by manipulating the *Neovius* equation. In this case, we multiplied 4 to 4 [cos(x) cos(y) cos(z)], which results in bigger size pores and void volume. Also, the transitioning geometry can be created by ramping geometric mixing protocol in *nTopology* from small- to large-sized *NeoBrick* prototypes. Lastly, angled prototypes were modeled by rotating inner geometries and Boolean intersections with the outer shell to trim unnecessary parts.

47.2.3.2 Performance Evaluation

It is essential to generate an optimized mesh quality for the final computational evaluation process. As the geometry becomes complex, it creates a significant amount of mesh faces and vertices. This potentially causes errors such as self-intersecting, non-manifold surface, or naked mesh. Therefore, the mesh was optimized to adequate resolution for the computational simulation but with significantly reduced number of mesh edges. The following optimization processes are conducted: (1) Create the high-resolution *NeoBrick* Mesh; (2) Re-mesh the surface with the longer edge length; (3) Voxelize the mesh to remove all the mesh errors and reduce the number of mesh surfaces; (4) Then, the optimized mesh file is imported to CFD analysis platform, *Simcale*, without any geometric errors. The voxelized mesh with a 1.5 mm edge length that preserves the original shape of the geometry takes 3 min to be loaded into the simulation engine (Fig. 47.11).

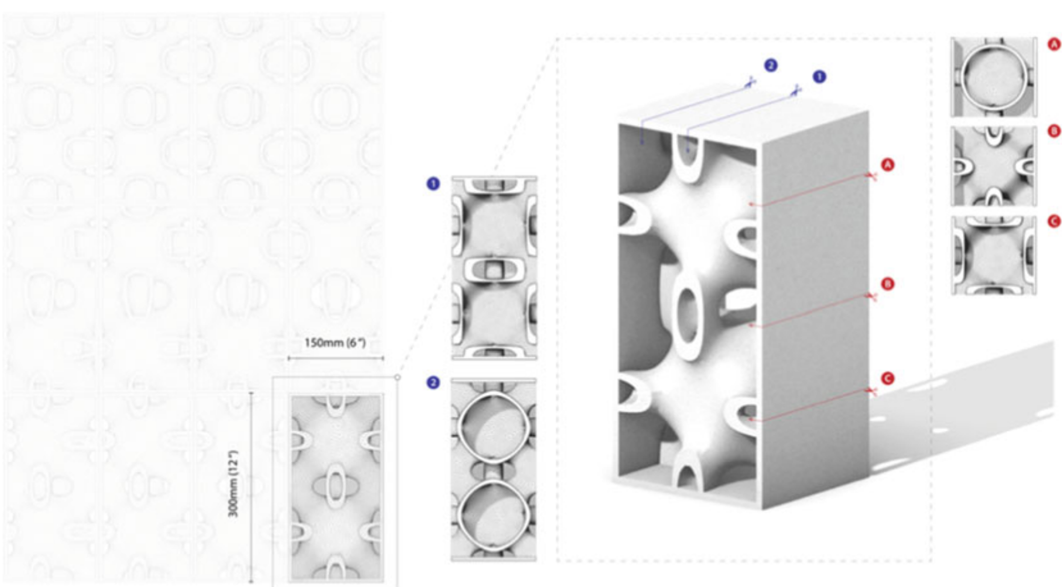

Fig. 47.9 Brick prototype comprised of Neovius inner geometry and outer brick shell

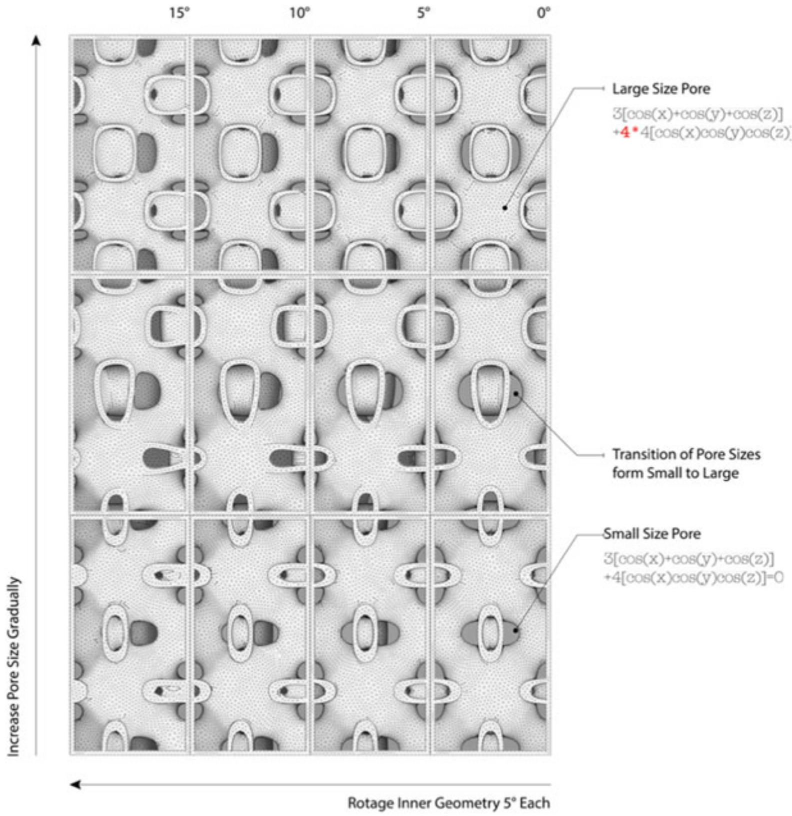

Fig. 47.10 NeoBrick prototypes with controlled pore sizes and directions

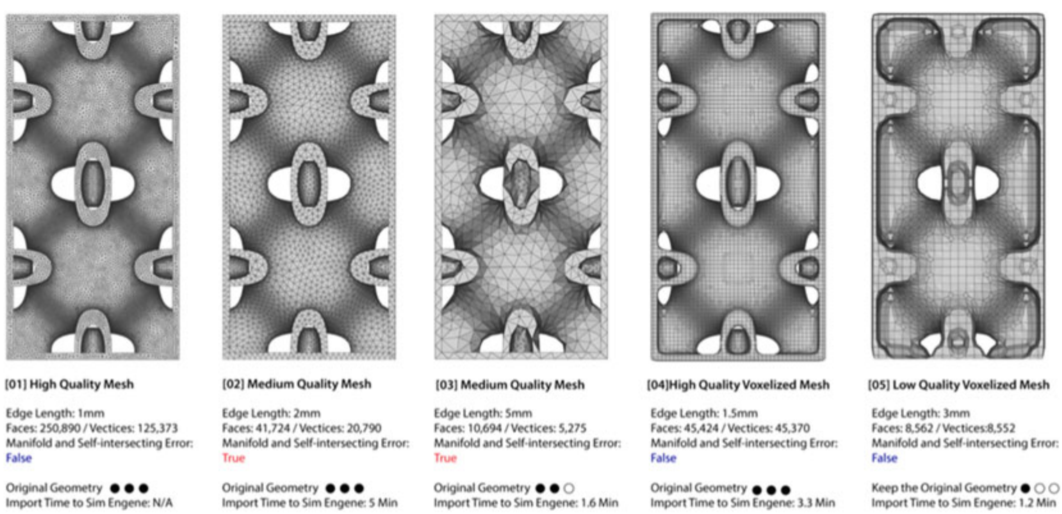

Fig. 47.11 Optimized mesh quality studies for CFD analysis

The air modulating performance of one brick prototype, small-sized pore without rotation, was first evaluated by using CFD simulation. Compared to the early iterations, this geometry has a larger void volume, where the larger amount of air can be passed and accelerated at a certain vertical section of the outlet channel (Fig. 47.12). In horizontal sections, it is air penetrable with increased air velocity at each different cross-sectional area due to the wind funneling effect (Fig. 47.13).

The vertical arrangement of different pore-sized brick prototypes generates a smooth transition of opening sizes from small to large. The simulation result shows that the large pore-sized and transition brick prototype are more air penetrable than the small pore-sized brick geometry. The large pore-sized prototype, which is manipulated by changing the *Neovius* equation, allows a larger amount of air to be passed through its hollow volume. Moreover, all pores accelerate the airflow, but it shows the pressure drop at the outlet channel (Fig. 47.14).

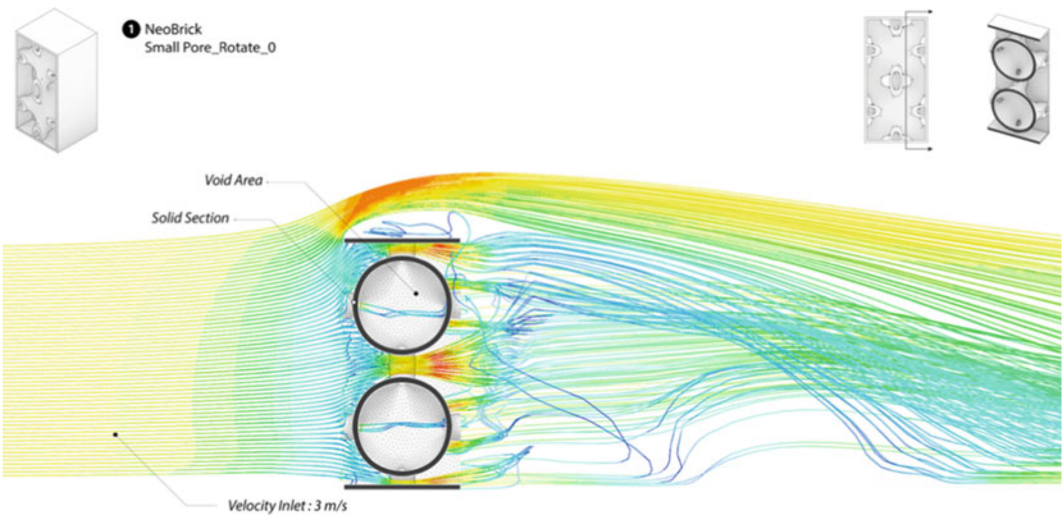

Fig. 47.12 Vertical cross-section of CFD analysis of NeoBrick prototypes with Small Pore sized geometry

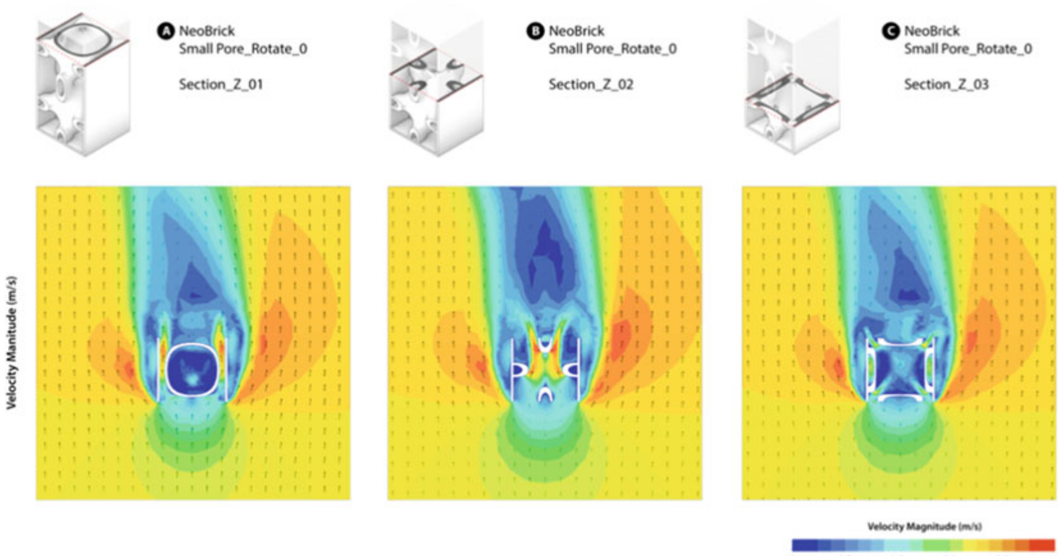

Fig. 47.13 Horizontal cross section of CFD analysis of NeoBrick prototypes with small pore-sized geometry

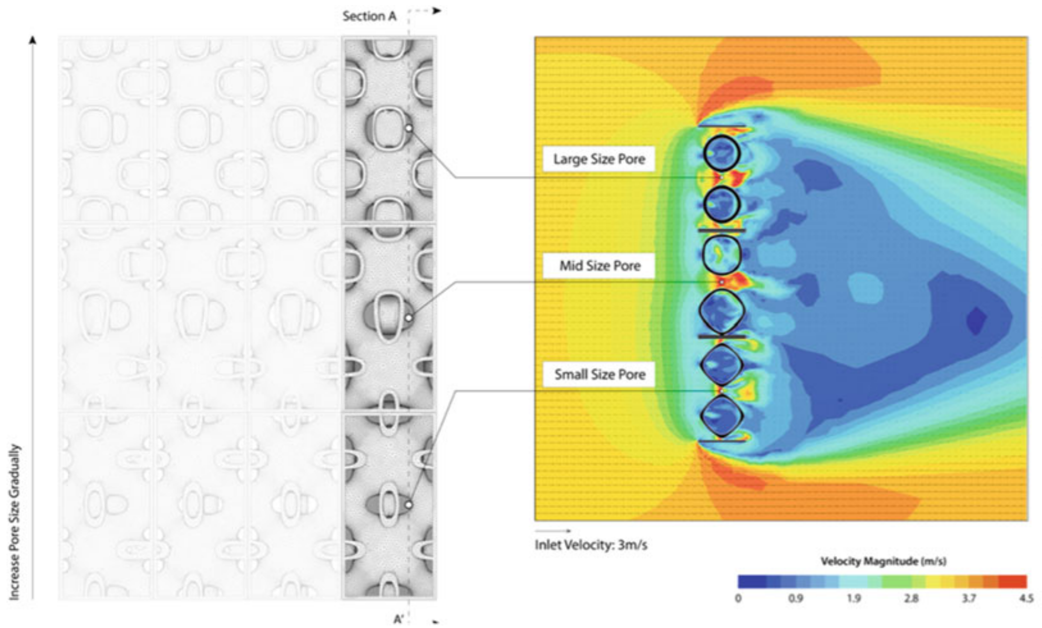

Fig. 47.14 CFD analysis NeoBrick prototypes featuring different pore sizes

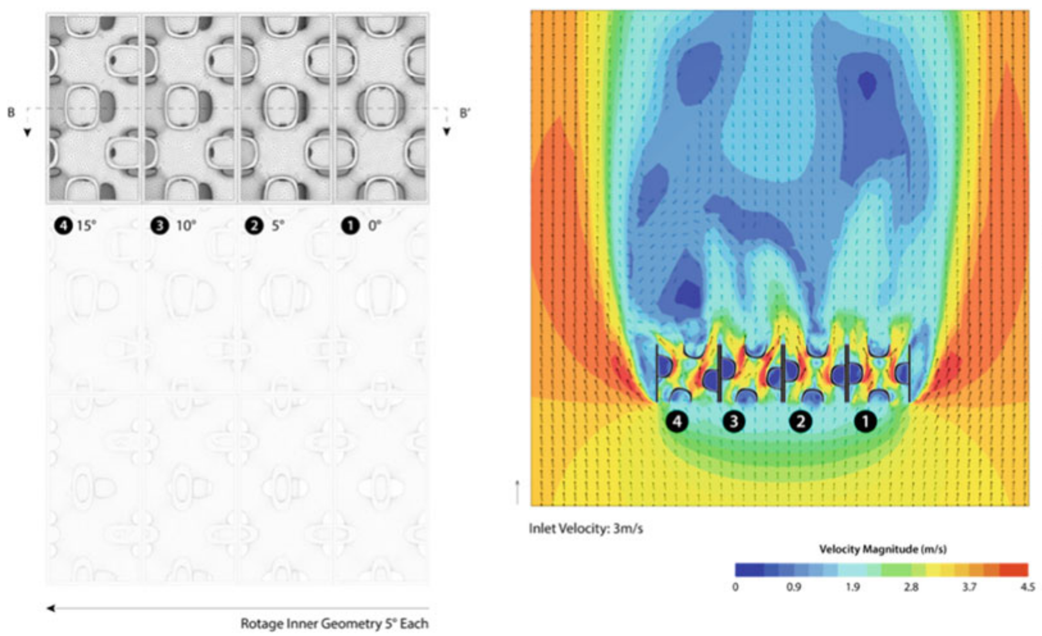

Fig. 47.15 CFD analysis with different angled inner geometries of NeoBrick prototypes

The CFD analysis with horizontal arrangement of angled inner geometries validates the airflow directing functionality of the *NeoBrick* prototype. The differently angled inner geometry affects the direction of the airflow outlet. In this case, the overall air at the outlet channel flows toward the right side due to the gradual rotation of every 5 degrees clockwise for each geometry (Fig. 47.15).

47.2.4 Fabrication Process

This research uses high fire stoneware clay as a primary material because of its accessibility and thermal properties. Clay 3D printing is an emerging additive manufacturing technology informed by several design drivers enabling designers to fabricate non-standard geometries of architectural components. This research also leverages clay 3D printing technology to fabricate an environmentally informed lattice-structured brick prototype. *3D PotterBot*, a clay 3D ceramic printer, is used for this fabrication stage. In an early fabrication approach, the GCODE file was generated using a typical slicing tool. The print outcomes were unsuccessful in resolution (Fig. 47.16). It required its own strategies for custom toolpathing since the complex geometry includes a thin surface with drastic angles and overhanging segments.

Therefore, the following pipeline for custom toolpathing was structured to increase the printability of the non-standard brick geometries. The custom toolpathing pipeline is the following: (1) Generate *Neovius*-informed brick geometry; (2) Optimize the mesh quality to higher resolution; (3) Contour the input mesh with desired layer heights for printing; (3) Sort and group curves by Z coordinate; (4) Divide curves and create target points for tool pathing; (5) Generate custom GCODE using a customized *grasshopper* script.

Even though the customized toolpath brought better print outcomes, it still extrudes unnecessary clay while it moves from one layer to the next. Therefore, each layer's start and end points are designated to enhance the linear movement of the extruder. The second set of toolpaths with start and end point modification show more linear movements of the extruder than the first toolpath iterations. It connects layers smoothly and minimizes the unnecessary extrusion of clay (Fig. 47.17). This consequently reduces the material usage while printing the physical outcomes that resemble the digital model very closely (Fig. 47.18).

The fabrication process with a custom tool path strategy follows each phase of the brick design iterations. Test prints start with the small-scale *Neovius* walled surface structure to examine the custom toolpath strategy. Then, the first iterations of *NeoBrick* with solid TPMS bodies are printed. This step suggests that this solid brick body consumes a large amount of clay material and takes longer to print. Therefore, the final brick iterations are developed to feature a thin *Neovius*-informed inner shell with increased void volume. The final *NeoBrick* prototype is fabricated in full scale using a clay 3D printer (Fig. 47.19).

47.3 Result

47.3.1 Architectural Application

The paper intends to propose a possible architectural application of *NeoBrick* as a composite

Fig. 47.16 Early trial clay prints using GCODE automatically generated by the slicer

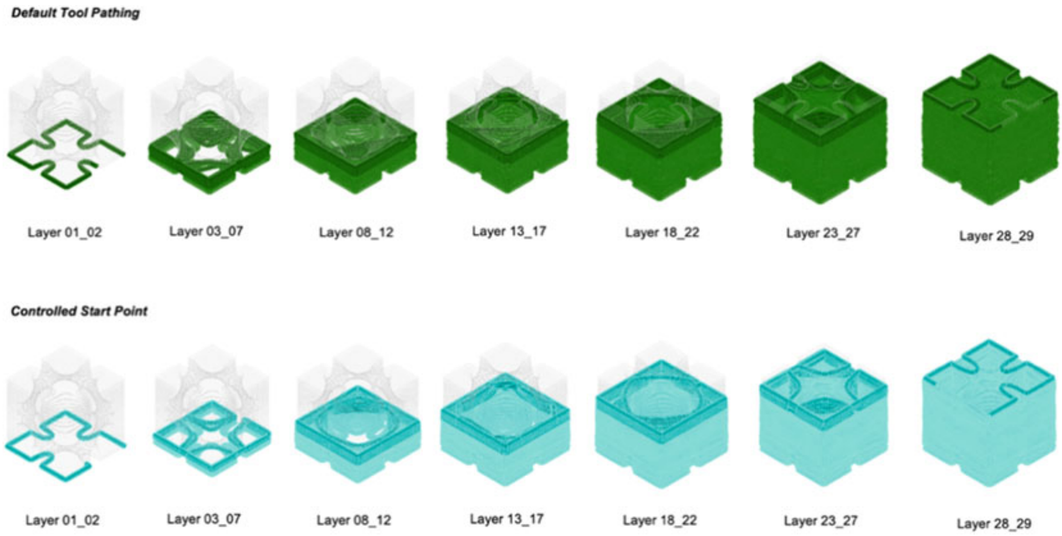

Fig. 47.17 Tool pathing simulation for each group of layers

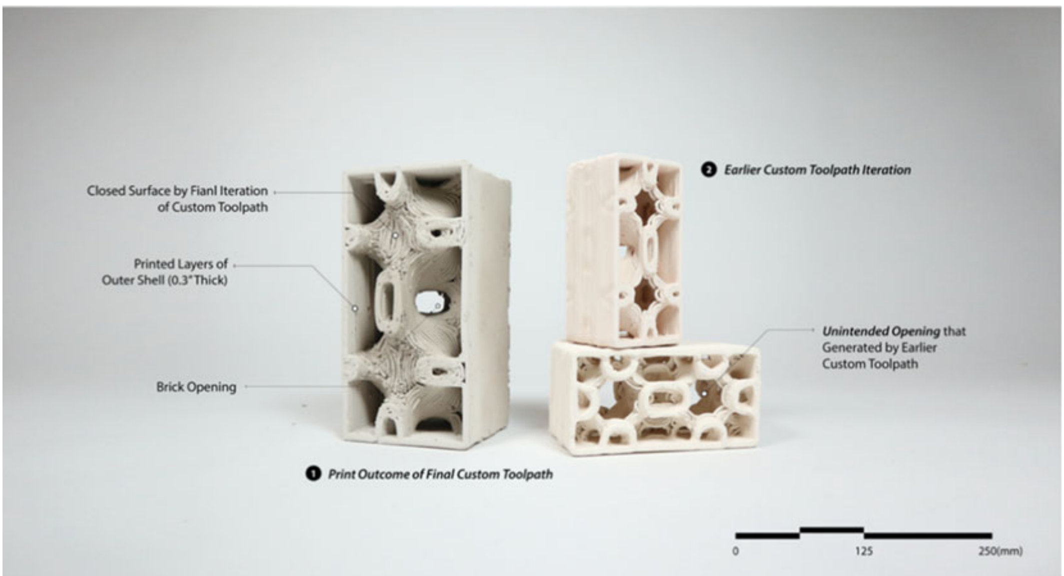

Fig. 47.18 Printed outcome using custom GCODE

perforated brick system. Ho Chi Minh City in Vietnam was explored for its climatic context and residential typologies featuring passive cooling strategies. Given the socio-climatic aspect mentioned earlier in this paper, new types of tube houses are emerging by integrating their design with environmental design drivers, including natural ventilation and daylight filtration, including local parameters such as user privacy. This climate-adapted design has been emerged in this region since the post-colonial period dwelling typologies (Anh et al. 2016). Built upon the existence of local knowledge, the *NeoBrick* system, situated in a local street block

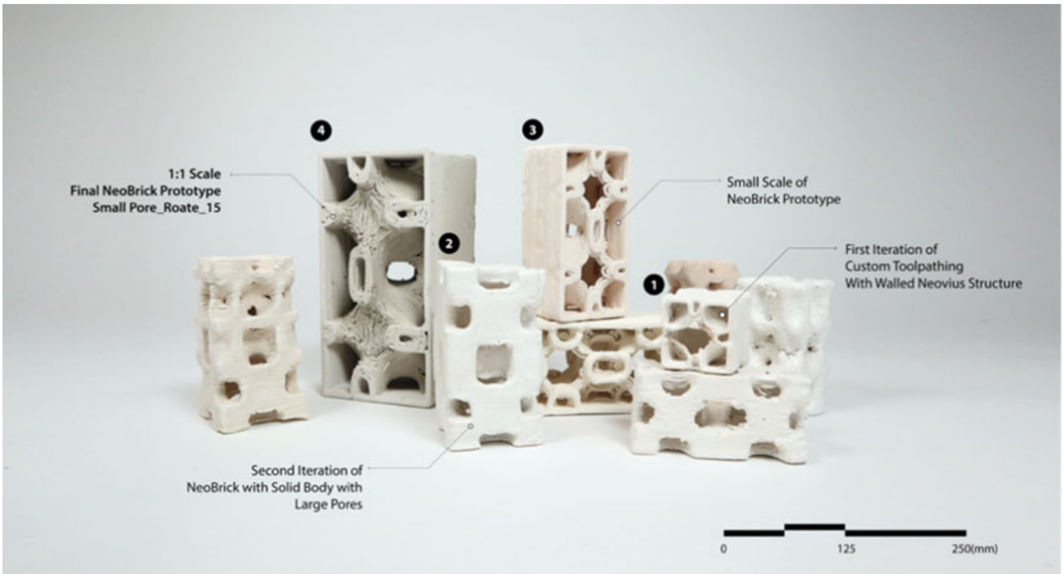

Fig. 47.19 Clay 3D-printed *NeoBrick* prototypes using custom tool pathing strategy

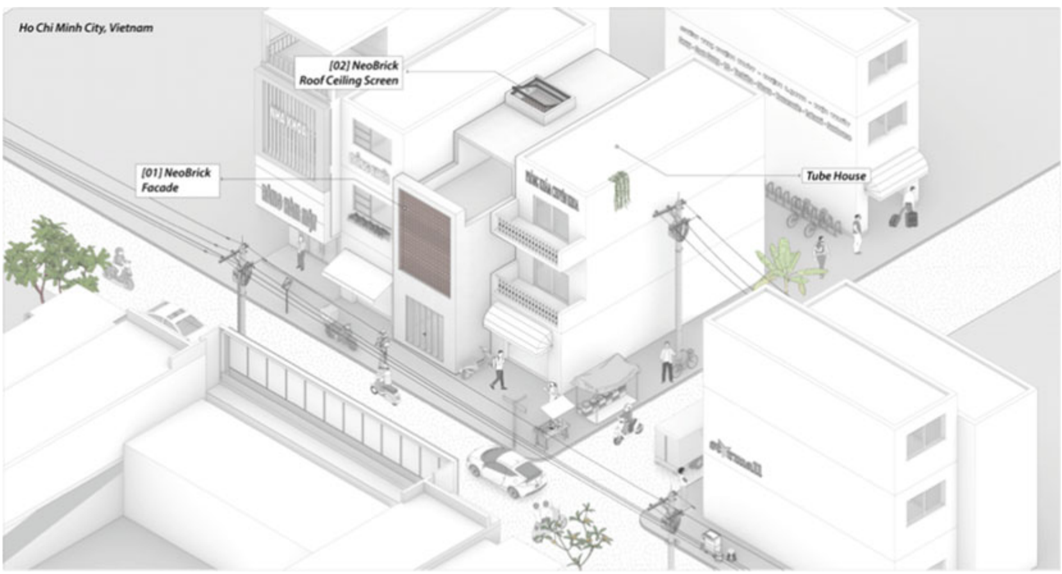

Fig. 47.20 Application of NeoBrick system situated in the local street block in Ho Chi Minh City

in Ho Chi Minh City, was programmed to control environmental factors through geometric properties. Therefore, the system environmentally performs as a perforated brick façade and roof window screen that facilitates the natural ventilation and filters the direct sunlight. Moreover, it protects residents' privacy from the densely populated street environment in this city (Fig. 47.20).

In detail, both the *NeoBrick* façade and roof window screen can be integrated, constructed, and bound together, in the same way as typical masonry construction. Furthermore, with the secondary system, the user can decide whether to open or close the indoor space in response to climate conditions with features like a folding glass door and a center-pivot roof window (Fig. 47.21).

As an integrated set of design parameters that control indoor thermal and visual comfort, the proposed architectural application echoes many projects presented in this paper's research background while recalling the original environmental functionality of tube house that has been diminished due to socio-economic issues. On the one hand, Erwin Hauer's screen system, for instance, made a paradigm shift in composite

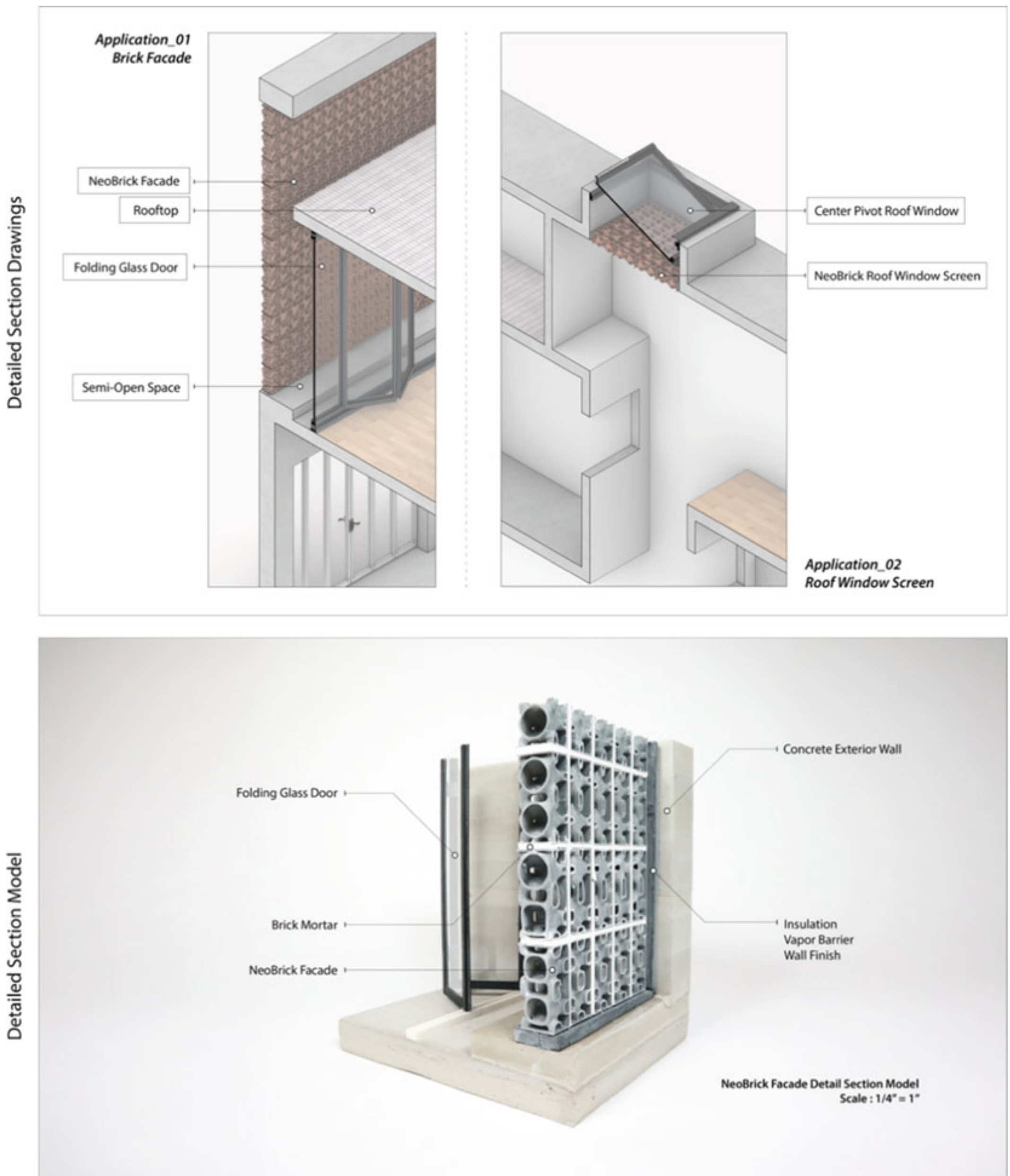

Fig. 47.21 Detailed section drawings (Top) and model (Bottom) of NeoBrick system

architectural components. The prototyped modular units are designed using mathematical parameters, which generate seamless and continuous geometries. It filters daylight and creates distinctive forms of shadow through its porous geometries. On the other hand, contemporary examples addressed earlier in the paper, *Integration of CFD in Computational Design* and *Cool Brick*, suggested performance-driven clay wall and brick prototypes fabricated using additive manufacturing technologies. Their geometries facilitate environmental performances, including natural ventilation and passive cooling, to control the indoor environment. In parallel with those examples, *NeoBrick,* a TPMS-informed perforated brick, expanded its functionality and aesthetics by synthesizing the design feedback process utilizing multiple environmental parameters with the use of customized addictive manufacturing technologies. *NeoBrick,* a high-performance 3D-printed clay brick system, was also expected to perform as a light diffuser but also wind-penetrable brick system that enhances the indoor living experience in specific climate conditions (Fig. 47.22).

47.4 Discussion and Conclusion

NeoBrick highlights an integrated research streamline that develops non-standard forms of porous brick prototypes informed by environmental parameters, including airflow and heat transfer. The performance-driven brick geometries are fabricated by exploring clay additive manufacturing technologies. This research demonstrates the possible architectural application of *NeoBrick* in a specific climate context as an environmentally responsive architectural system, which also interacts with its socio-cultural urban context (Fig. 47.23).

The research successfully leveraged the computational performance analysis, including computational fluid dynamics (CFD) and conjugate heat transfer analysis, to inform brick geometries. This multi-year investigation rigorously researched the behavior of airflow affected by geometric conditions as active design feedbacks. The project utilized customized protocols of clay additive manufacturing technology to fabricate non-standard forms of brick prototypes. The specific usages of the brick,

Fig. 47.22 Rendered indoor space where direct natural light is filtered through NeoBrick Façade

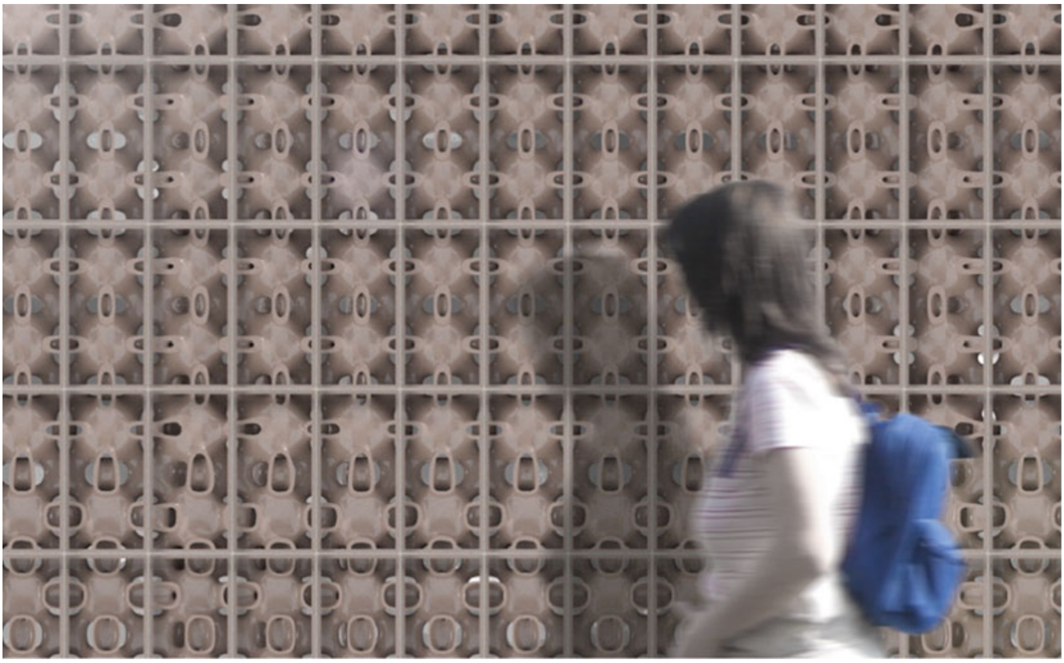

Fig. 47.23 NeoBrick Façade facing to the public street

including façade, roof ceiling screen, and window screen have been addressed in this paper. In the future research, these usages need to be compared and validated through simulations. The use of extended environmental parameters such as solar radiation and energy assessment will be pursued for supporting the research's hypothesis. Moreover, the global performance assessment is also required as an immediate next step to test a possibility of *NeoBrick* as a universal brick system that can be employed in a wide range of regions in different climatic conditions. The physical assessment of thermal transfer, airflow modulation, and structural performance with 1:1 scale *NeoBrick* wall prototype would be an alternative evaluation method to consider.

In summary, the integration of design and emerging technologies with a specific vernacular housing typology featuring passive cooling has opened the possibility for new design methods and approaches toward thermal performance and passive cooling through innovative additive manufacturing methods coupled with simulation and advanced geometry. In sustainable design practice, 3D printing techniques have enabled designers to explore irregularly shaped geometries informed by various design parameters. Thermal comfort is one such environmental parameter and is closely integrated and influenced by the variegated brick component configurations. Thus, this paper introduces a synthetic design workflow that develops a clay 3D-printed porous brick system informed by environmental parameters such as airflow and thermal performance. In a specific climatic context, the *NeoBrick* system is expected to provide residents with comfortable indoor environmental conditions through natural ventilation and the filtering of direct natural light through its nonstandard geometry. We hope this research pipeline will further contribute to studies that intend to explore the potential reduction of energy usage or control of thermal comfort by leveraging a passive ventilation strategy coupled with emerging technologies, additive manufacturing of brick components, and environmental parameters as design drivers.

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