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DESIGNING AND TESTING THE APPLICABILITY OF A NATURAL GREEN VENTILATION BUILDING BLOCK IN AN EGYPTIAN CLIMATIC ZONE USING WASTE MATERIALS

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ABSTRACT

Natural ventilation is one of the ways used to enhance building spaces' indoor air quality, especially after the COVID-19 pandemic. It also saves energy by utilizing natural wind forces to provide internal building spaces with fresh air instead of energy-consuming mechanical systems. For a multiple-floor building, adding external wall ventilation blocks can improve natural cross ventilation by catching and directing fresh air from the external prevailing wind into its internal spaces. This research aimed to enhance the building's natural ventilation by using environmentally friendly blocks. This was done by designing a green block using marble and granite waste materials as a partial substitute for conventional materials in the block. Styrofoam beads were added to the block's mixture to reduce its weight. The block's shape was designed to direct fresh air through building side walls by the use of natural wind pressure. The block was developed from the initial shape of the standard hollow block to a block with a wind catcher. Ventilation block shape simulations were done using (ANSYS fluent) computational fluid dynamics (CFD) software to determine the best inlet angle, catcher angle, and catcher length. The study revealed that by increasing the block inlet angle more than 45°, the block outlet air velocity starts to decrease due to the flow separation in the front part of the block inlet. The catcher angle ranged from 65° to 85°, and the catcher's ability to redirect the airflow is decreased at a catcher angle greater than 85°. The best nondimensional catcher length-to-block length ratio (height /length) h/L was 0.625. Substitution of 5% of cement by granite in the presence of 0.15 Kg of Styrofoam (C5G) produced a lightweight green ventilation block of weight 19.3 kg. Whereas, the substitution of 15% of sand for marble in the presence of 1 Kg of Styrofoam (S15M) produced a lightweight green ventilation block of weight 15.9 kg. The produced block was tested in a building located in New Cairo City (a region currently having a tremendous increase in the building construction sector) as a study sample representing one of the Egyptian Climatic zones. The research concluded that it is preferred to allocate the building corners towards the prevailing wind direction to prevent airflow separation and to magnify the quantities of air along the building sides.

Keywords: natural ventilation in buildings, ventilation blocks, marble and granite waste materials, Egyptian climatic zones, fluid dynamics computer simulation.

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1. INTRODUCTION

Natural ventilation is traditionally used for building spaces and human thermal comfort. Natural ventilation saves energy by replacing mechanical cooling or contributing to providing the energy required to cool building spaces [1]. Natural aeration blocks have been used historically in many hot regions. Ventilation blocks are building blocks with openings that allow air to circulate through the building spaces [2]. The shape and size of the block ventilation openings, as well as the orientation, affect the speed and amount of air passing through the wall. Ventilation block shape design differs according to the characteristics of the climatic region it is going to be built. Ventilation blocks revive building shapes with a heritage character, which is a unique way to achieve an architectural vision of environmentally friendly materials. Natural ventilation blocks encourage design skills towards creating futuristic ideas using environmentally friendly materials and enable the release of free architectural ideas far from the classic building design methods. Geographical Information Systems (GIS) play an important role in various sectors of the economy to make short and long-term decisions that involve socio-economic and environmental problems on a large scale so; it can be also used to represent the climatic characteristics of different Egyptian regions as illustrated in Figure-1. [3] The geographic information system provides through the research a climatic map showing wind direction distribution located on the buildings throughout the year, followed by using computer simulation software to study the appropriate block design shape and its opening size for each climatic region within the study [4].

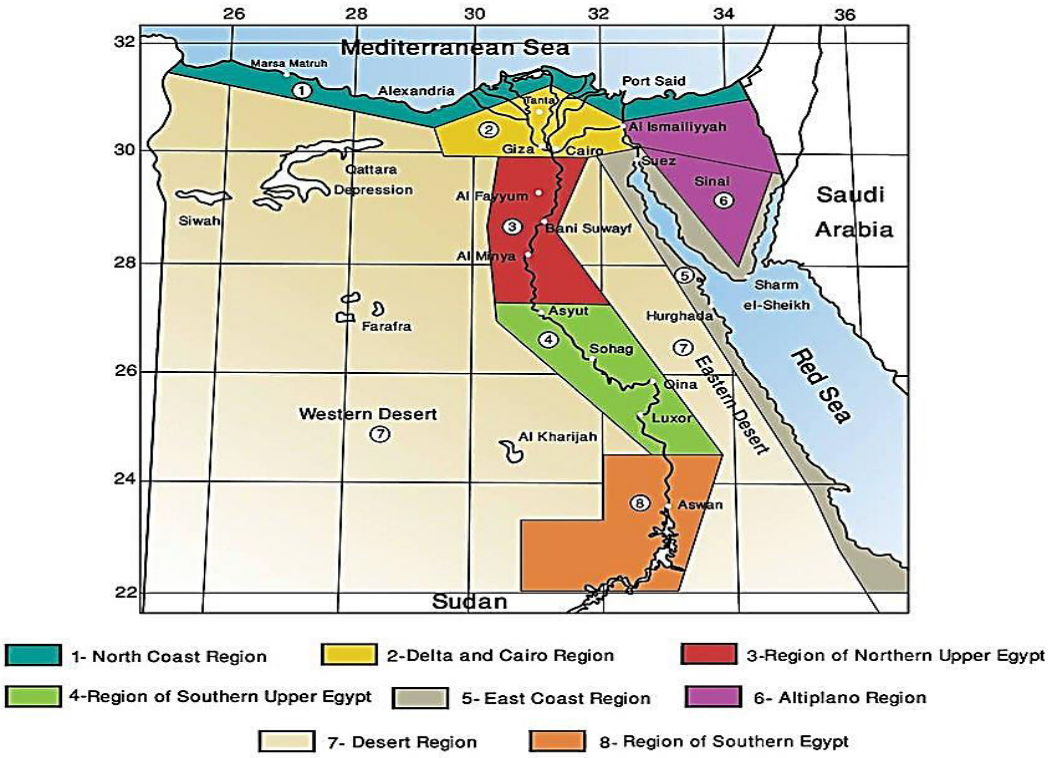


Figure-1. Egyptian climatic regions [3].

The World Health Organization (WHO) has proposed the minimum ventilation rate required to prevent any spread of airborne infections. According to a study conducted by Escombe, it was found that the risk of airborne infection is higher in areas where mechanical ventilation is used compared to similar areas that were using natural ventilation [5], [6], [7]. Three basic elements should be considered when dealing with building ventilation:

a) Ventilation, the process of supplying air to or removing air from space to control air contaminant levels, humidity, or temperature within the space [8].
b) Ventilation rate, which could be defined as the amount and quality of outdoor air that is provided into the room. Normally, the ventilation rate is expressed in units of air changes/hour, calculated as the total air volume supplied in one hour divided by the room volume [9].
c) Air distribution or airflow pattern by which the air should efficiently flow to the building space and the airborne pollutants generated in each part of the space should also be removed efficiently. The airflow direction is the overall air movement direction in space.

Catching and directing fresh air passing by the external building envelope to the inside of building spaces either for occupants' thermal comfort or natural ventilation is recognized in many historic buildings located in hot arid zones [10]. Wind flow passes by building roofs and induces wind pressure on their external walls. Although catching and directing wind flow passing by the building roof is preferable as wind flow is not interrupted by surrounding building masses, the wind-catchers have limitations on the building height [11] [12]. Catching and directing fresh air using roof wind catchers to the internal spaces of various building floors has to pass by vertical air shafts, which affect the airflow intensity unless the system is combined by getting used of negative wind pressure through leeward space openings or air thermal buoyancy by the use of solar chimneys [13]. Previous studies using (CFD) computational fluid dynamics software were performed for the effect of roof wind-catcher design [14] and [15], top shape [16], height above the building roof [17], vertical air duct dimension, intake louvers dimensions, and inclination angles on its efficiency for catching and directing prevailing wind to the inside of the building spaces.

1.1 Climatic Region

The research work was applied to New Cairo city as a study sample representing the Egyptian Climatic Region Figure-2. The Climate and Average Weather Year-Round at New Cairo are illustrated as follows: The percentage of average wind direction for each of the four wind directions, except that the average wind speed is less than 1.0 mph. Slightly colored areas on the boundary are the percentage of hours spent in the branching implicit directions such as (Northeast, Southeast, Southwest, and Northwest). [18]

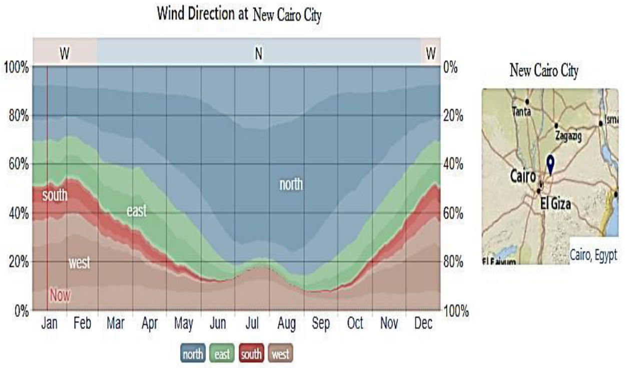


Figure-2. Average wind directions percentage (New Cairo City).

The predominant wind direction through Climatic Region (New Cairo City) is most often in the North direction. It is recommended that future buildings in New Cairo are to be oriented with their corners toward the North direction as shown in the wind rose in Figure-3. [19]

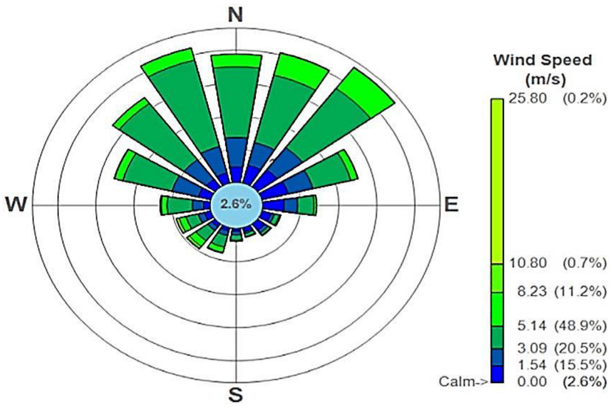


Figure-3. Wind rose for Cairo [19].

1.2 Driving Forces of Natural Ventilation

Although three forces: wind pressure, stack pressure, and mechanical force, can drive air through and inside buildings, this research focuses on the use of wind pressure.

1.2.1 Wind pressure

When buildings are exposed to wind, it causes both positive and negative pressures. This causes air to be forced through vents downwind (low-pressure vents against the wind) of the building. [20], [21].

The wind pressure generated on a building surface is expressed as the pressure difference between the total pressure on the point and the atmospheric static pressure. Wind pressure data can usually be obtained in wind tunnels by using scale models of buildings. If the surrounding condition of the building and all its geometry and wind direction are the same, then the wind pressure is directly proportional to the square of the external wind speed. Thus, the wind pressure is usually standardized by dividing it by the dynamic pressure of the external wind speed. The standardized wind pressure is called the wind pressure coefficient and is symbolized as Cp. The outdoor wind speed is usually measured at the height of the eave of the building in the wind tunnel (equation 1):

$$C_p=P_{t\text{-}}P_{AS}/1/2\rho^{V2}{}_{H} \qquad \text{……………………………..… (1)}$$

Where:

C_p	=	Wind pressure coefficient
P_t	=	Total pressure (P_a)
P_{AS}	=	Atmospheric static pressure at building height (P_a)
ρ	=	The density of air (kg/m^3)
$^{V}{}_{H}$	=	Wind velocity at a remote site from surrounding influences at the building height (m/s). [22].

2. RESEARCH METHODOLOGY

The research methodology is stated by Collecting previous information from most recent research concerning methods of a building using natural ventilation, its results, and conclusions, especially in Egypt. The ventilation blocks design stage started by simulating 2D ventilation block shapes. The next stage of simulation included studying the computer experimental models under real weather conditions according to various Egyptian climatic zones, reaching the best shape for the Ventilation block to be used in that Geographic area. The design stage ends with computer models for climatic types of Ventilation blocks. This stage includes the optimum designed ventilation block shapes and their manufacturing. Finally, the results will be discussed and the most important conclusions and recommendations of this research will be illustrated. Figure-4 illustrates this methodology.

Figure-4. Research methodology.

3. MATERIALS AND METHODS

The research studies the effect of ventilation block shape on the airflow pattern inside building space. The research started by examining the effect of using the standard double cavity 20Cm x 40Cm x 20Cm hollow block (used in construction) as a ventilation block. The standard concrete hollow block can be used as a ventilation block if it is placed where the hollow parts face the wind direction. Accordingly, the block geometry has been modified by adding a wind catcher part to its original shape. This aims to facilitate grasping more wind and letting it enter the required space to be ventilated. The research conducted a parametric study using numerical simulation to determine the best block inlet angle, ventilation block wind catcher angle, and length. As per the computer simulation recommendations, a physical model was built using polyethylene boards and examined in front of a parallel source of airflow. The experiment compared the standard concrete 40*40*20 Cm. hollow block Figure-5 and the Figure designed modified geometrical ventilation block shown in Figure-6.

Consequently, airflow under similar conditions has been plotted and compared for both blocks.

Figure-5. Standard 40*20*20 Cm. concrete hollow block.

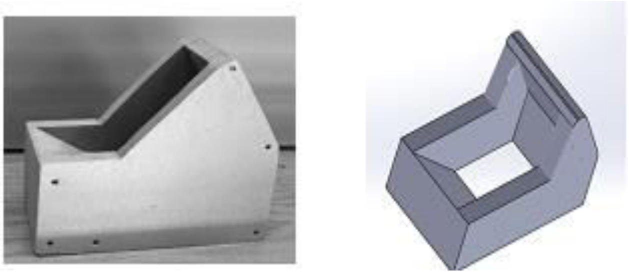


Figure-6. Designed modified geometrical ventilation block.

3.1 Numerical Discretization

There are three steps required to perform the numerical simulation. The first step is creating models and surrounding domains. Constructing the mesh is the second step required for the simulation done by using Pointwise commercial software. The final step is using ANSYS FLUENT 20 commercial software packages as a solver based on a cell-centered finite volume approach to solving the Navier-Stokes equations, which consist of partial differential equations (PDEs) describing the laws of conservation for continuity, momentum, and energy equations. Calculations are performed by Work Station with 24 cores and 48 Giga Rams.

3.1.1 Computational domain and boundary condition

The designed block variables used in the simulation are shown in Figure-7. Block length (L) 0.4 m, block inlet angle is altered in the design to have slopes with angles of 30°, 45°, 60°, and 75°. The wind catcher length is altered to 0.25 L, 0. 375 L, 0. 5 L, 0.625 L, 0.75 L, 0.875 L, and 1 L, where L is the block length. The wind catcher angle is altered to 15°, 25°, 35°, 45°, 55°, 65°, 75°, 85°, 95°, and 105°.

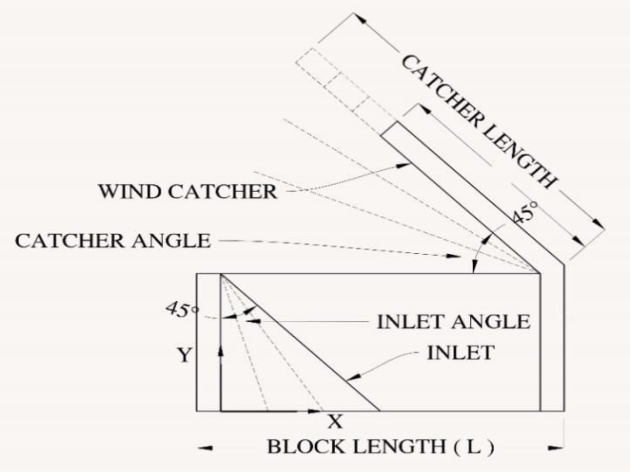


Figure-7. Designed block variables in simulation.

The outer domain is constructed as shown in Figure-8(a). The outer domain is extended 20 times the block length upstream and 30 times downstream. The height of the domain is designed to be 20 times the block length. The inlet and outlet of the domain are defined as the velocity inlet and pressure outlet, respectively. The upper side of the domains is set to a symmetric boundary condition. The room of the attached block is a square room with a wall length of 7.5 L, and it is defined as the wall boundary condition. The opposite room side of the block is defined as the pressure-out boundary condition. The block wall is defined as wall boundary condones, as seen in Error! Reference source not found. (b).

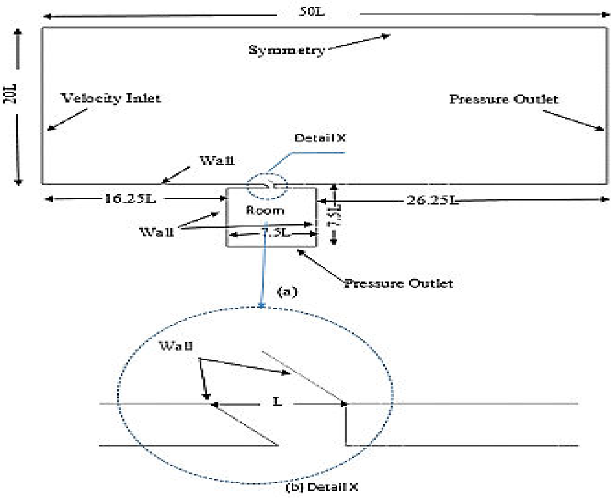


Figure-8 (a, b).

3.1.2 Ventilation flow rate

As a rule of thumb, the wind-driven natural ventilation rate measured in liters per second (l/s) through a room with two opposite openings (e.g., a window and a door) can be calculated as follows:

ACH = (0.65 X Wind speed (m/s) x smallest opening area (m2)x 3600 s/h) / room volume (m3)

Ventilation rate (l/s) = 0.65 x wind speed (m/s) x smallest opening area (m2) x 1000 1/m3. Error! Reference source not found. provides estimates of the ACH and ventilation rate due to wind alone at a wind speed of 1 m/s, assuming a ward of size 7 m (length) × 6 m (width) × 3 m (height), with a window of 1.5 × 2 m2and a door of 1 m2 × 2 m2 (the smallest opening).

Table-1. Estimated air changes per hour and ventilation rate for a 7 m ×6 m × 3 m ward the wind speed refers to the value at the building height at a site sufficiently far from the building without any obstructions. [22]and [23].

Openings	ACH	Ventilation rate (l/s)
Open window (100%) + open door	37	1300
Open window (50%) + open door	28	975
Open window (100%) + closed door	4.2	150

4. MATERIALS USED

The normal conventional cementitious brick/block is usually composed of a mixture of Portland cement, water, and fine and coarse aggregates. The properties of all materials used in this research were determined according to the Egyptian Standard Specifications and the recommended code of practice [24].

4.1 Portland Cement

Commercial Torah Portland-limestone blended cement (OPC) with a fineness of 9 % passing from sieve 170 and its relative density (specific gravity) was 3.15. Its initial and final settings were 2hrs and 3hrs 12 minutes resp.

4.2 Aggregates

Natural sand from pyramids quarries in Giza with a maximum size of 4.75 mm was used as fine aggregate. Two sizes of course aggregates were used in the study with a maximum nominal size of 19 mm. (2 sizes).

4.3 Waste Materials Characterization

Granite and marble sludge powders were used as a partial substitution for cement and sand in this study. The waste materials were obtained as a by-product of granite and marble sawing and shaping from Egyptian marble factories (saw gang granite type from Shaq Al-Thu'ban zone). The wet granite and marble sludge samples were dried in an oven at a temperature of 200 C for 6 hours before the preparation of the cementitious bricks to have a constant W/C ratio. The stone powder was then weighed before and after drying (the difference should be less than 10%) to ensure minimum water content. The stone waste used for replacement has particles passed through sieve no. 200. Chemical analysis of the slurry powders was determined by elemental analysis using Wavelength Dispersive X-Ray Fluorescence Spectrometry, as shown in Tables (2) and (3). Marble powder shows calcium oxide as the major component >53% with a loss of ignition (LOI) of around 42% and small amounts of SiO2 and Fe2O3. On the contrary, granite shows SiO2 as the major component around 70% with a much lower level of LOI <1%. [25] and [26].

Table-2. Chemical analysis of marble gang saw sample.

Marble Main Constituents	(wt%)
SiO_2	1.34
TiO_2	0.02
Al_2O	0.23
Fe_2O_3	0.023
MgO	1.99
CaO	53.14
Na_2O	0.05
K_2O	0.04
P_2O_5	0.02
Cl	0.03
LOI	42.65
MnO	0.028
NiO	0.009
SrO	0.032

Table-3. Chemical analysis of granite gang saw sample.

Granite Main Constituents	(wt%)
SiO_2	70.08
TiO_2	0.33
Al_2O_3	14.27
Fe_2O_3	3.23
MgO	0.56
CaO	1.11
Na_2O	5.54
K_2O	3.61
P_2O_5	0.21
SO_3	0.06
Cl	0.06
LOI	0.61
MnO	0.128
NiO	0.004
CuO	0.028
ZnO	0.018
SrO	0.019

4.4 Sampling and Testing

To evaluate the mechanical and physical properties of the ventilation blocks, each mix was prepared to obtain 4 standard bricks (25*12*6) cm and 1 ventilation block. The compression strength and density of the bricks were monitored according to the Egyptian Standards requirements for bearing cementitious standard bricks and blocks. This technique of evaluation was the basis for testing the success or failure of the mix used to cast the ventilation block. Primarily, a basic mix of conventional materials with proportion 1:3.5:2.75:2.75:0.5 of cement: sand: fine coarse: coarse: w/c respectively was cast as shown in Figures 9(a), and 9 (b), to obtain a ventilation block with the required dimensions. After curing the block weight showed 24.8 Kg which was very difficult to handle as a building unit.

Figure-9(a) and (b). Casting the ventilation block.

Secondly, to reduce the block's weight shredded Styrofoam was used as a residue waste of packaging Figures 10(a), and 10(b).

Figure-10(a) and (b). Styrofoam Shredding Machine.

At this stage of the tests, it was used different amounts of Styrofoam of weights ranging from 0.15 and 1 kg in the mixes. The resulting compression strength of the bricks was used to evaluate the ventilation blocks as presented in Table-4. The results showed a significant reduction in the block's weight by increasing the amount of Styrofoam in the mix. However, the increase in the Styrofoam content reduced the compression strength of the building unit. [27].

5. RESULTS AND DISCUSSIONS

The air velocity contours of standard 40*20*20 Cm. The concrete hollow building block is shown in Figure-11 and the designed block is shown in Figure-12. The standard 40*20*20 Cm building block has an insignificant role in ventilation, where two vortices are formed inside the block that reduces airflow through its openings. Whereas, the designed block. Figure-12 shows that the added catcher forces the airflow to be directed inside the building.

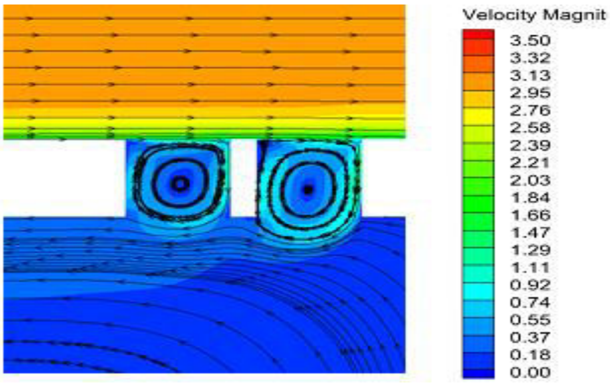


Figure-11. Velocity contour and stream function of Standard 40*20*20 Cm. Hollow Block.

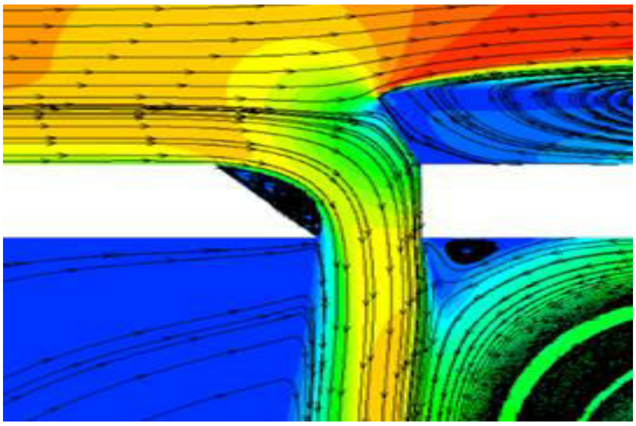


Figure-12. Velocity contour and stream function of the designed block.

The relation between the velocity magnitude at the blocked outlet to the free stream velocity ratio U/U∞ and the block outlet position to the original length ratio L/L0 is shown in Figure-13 The designed ventilation block increases the building air inlet velocity up to four times more than the normal (standard 40*20*20 Cm) building block. For the x-axis, 0 represents the first end of the block outlet and 1 represents the second end of the block outlet.

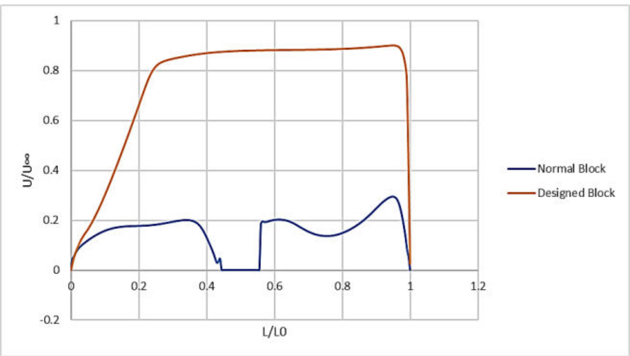
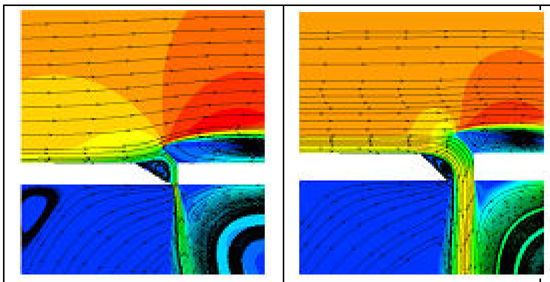


Figure-13. Relation between the velocity magnitude U at the blocked outlet to the free stream velocity U∞ ratio and block outlet position L to the original length ratio L0.

To obtain the best block ventilation performance, a parametric study was performed to reach the best ventilation block design shape which included the block air inlet angle, catcher length, and catcher angle.

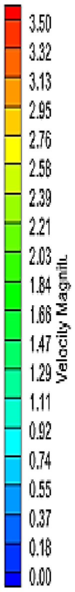
5.1 Block Inlet Angle

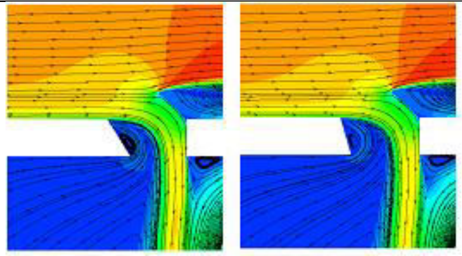
The block inlet angle is altered in design to have slopes with angles of 30°, 45°, 60°, and 75°, as seen in Figure-14 (a), (b), (c), and (d), respectively. The lowest block outlet area at 30° is shown in Figure-14 (a), and a large flow separation is formed at the inlet edge, which decreases the flow velocity passing through the block into the building. By increasing the inlet angle to more than 30°, at an angle of 45°, as shown in Figure-14 (b), the separation at the inlet block decreases, and the block outlet velocity increases. By increasing the block inlet angle to more than 45°, as seen in Figure-14 (c) and (d), a large flow separation is formed in front of the block inlet to decrease the outlet area, which in turn decreases the block outlet velocity. Figure-15 represents the relation between the nondimensional block outlet position and the nondimensional block outlet velocity magnitude at block inlet angles of 30°, 45°, 60°, and 75°. This figure shows that increasing the block inlet angle increases the block outlet velocity until an angle of 45° is reached. By increasing the block inlet angle by more than 45°, the block outlet velocity starts to decrease due to the formation of the flow separation in front of the block inlet, as mentioned before.



30° 45°

Figure-14 (a), and (b). Velocity contours and stream function of the building block inlet angle at (a) 30°, and (b) 45°.





60° 75°

Figure-14 (c), and (d). Velocity contours and stream function of the building block inlet angle at (a) 60°, and (b)75°,

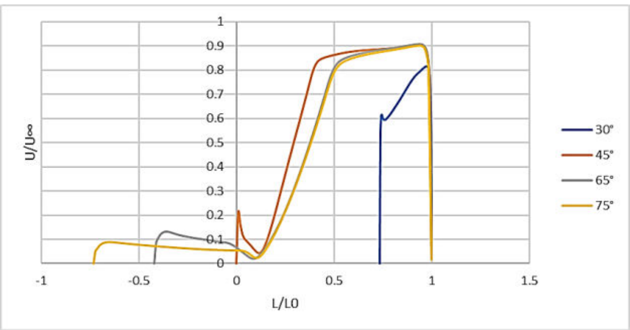


Figure-15. Relation between the nondimensional block outlet position and nondimensional block outlet velocity magnitude at block inlet angles of 30°, 45°, 60°, and 75°.

5.2 Catcher Angle

The wind catcher angle parameter plays an important role in block performance enhancement. The wind catcher angle is altered to 15°, 25°, 35°, 45°, 55°, 65°, 75°, 85°, 95°, and 105°, as seen in Figure-16 (a), (b), (c), (d), (e), (f), (g), (h), (i) and (j). At a catcher angle of 15°, a large flow separation is formed in front of the block inlet, as seen in Figure-14(a). By increasing the catcher angle, the flow separation starts to decrease, as shown in Figure-16 (b), (c), (d) & (e), at angles of 25°, 35°, 45° and 55°, which by turn increases the block outlet velocity to reach its maximum at angles of 65°, 75°, and 85°, as shown in Figure-16 (f), (g) & (h), respectively. The catcher's ability to redirect the airflow decreases at catcher angles greater than 85°, as shown in Figure-16 (i) and (j) at angles of 95° and 105°, respectively, which decreases the block outlet velocity.

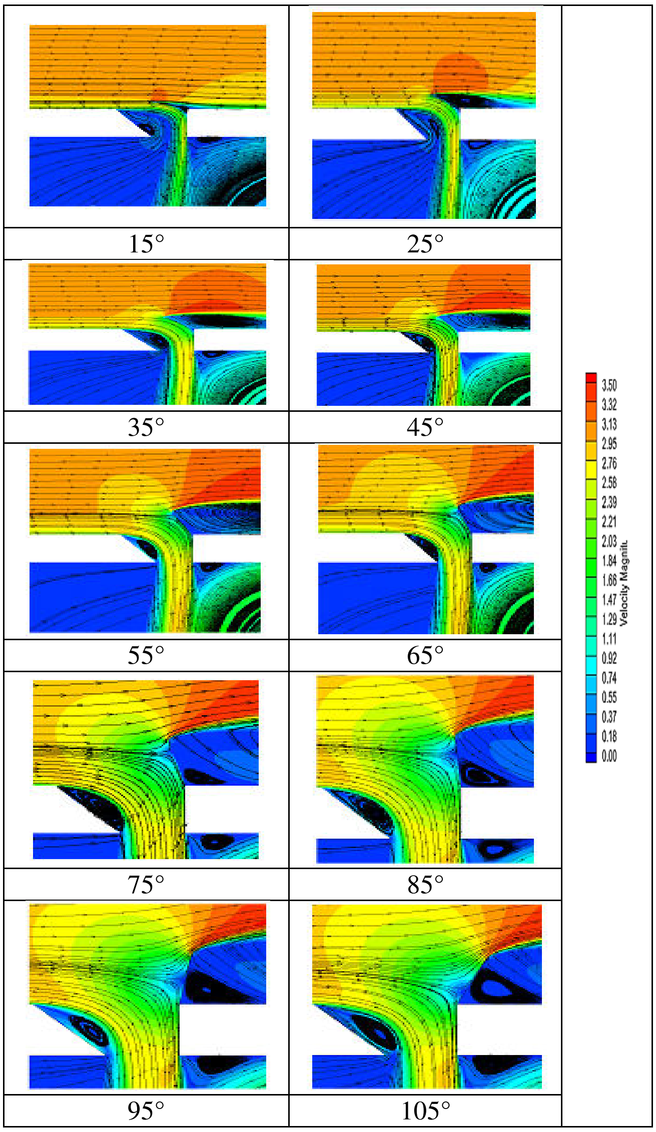

15° 25°
35° 45°
55° 65°
75° 85°
95° 105°

Figure-16. Velocity magnitude and stream function of the building block at different catcher angles: (a), (b), (c), (d), (e), (f), (g), (h), (i), and (j)

Figure-17 shows the relation between the nondimensional block outlet position and nondimensional block outlet velocity magnitude at catcher angles of 15°, 25°, 35°, 45°, 55°, 65°, 75°, 85°, 95°, and 105°. From the previous figure, it is concluded that the velocity magnitude at the outlet of the block increases by increasing the catcher angle until it reaches angles of 65° to 85°. By increasing the catcher angle to more than 85°, the velocity magnitude at the outlet of the block starts to decrease dramatically due to the wedge shape of the catcher.

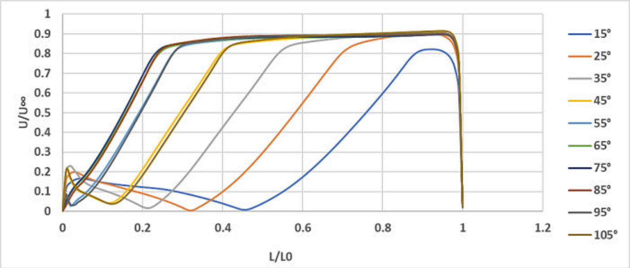
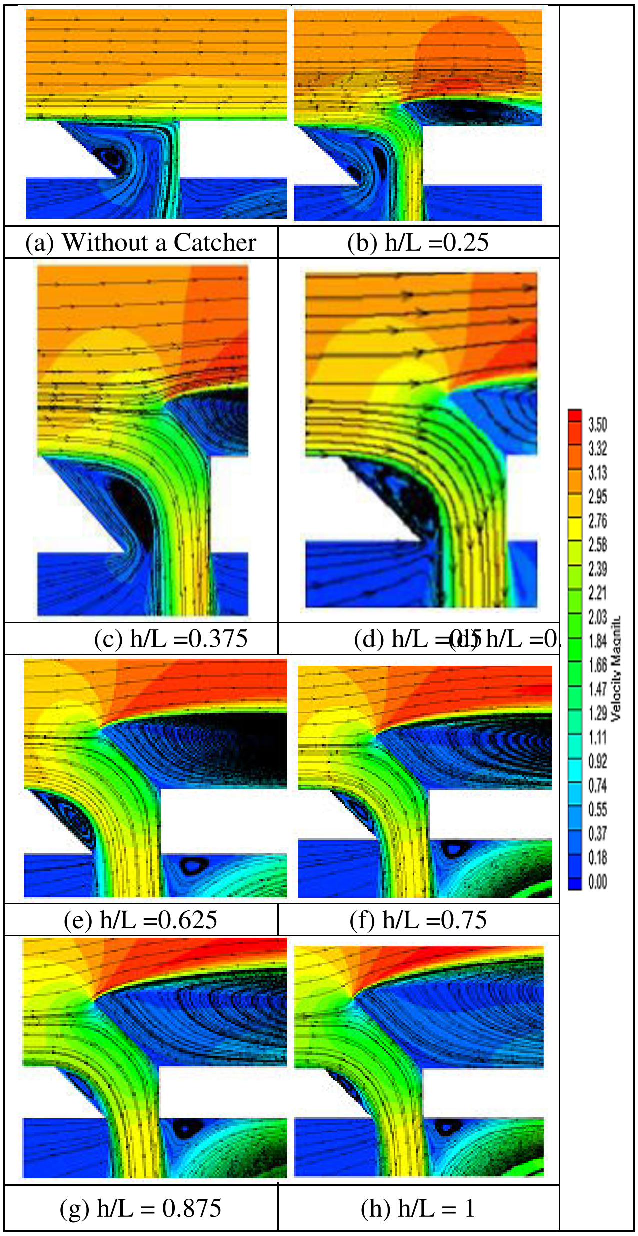


Figure-17. Relation between the nondimensional block outlet position and nondimensional block outlet velocity magnitude at catcher angles of (a) 15°, (b) 25°, (c) 35°, (d) 45°, (e) 55°, (f) 65°, (g) 75°, (h) 85°, (i) 95°, and (j) 105°.

5.3 Catcher Length

The catcher length plays an important role in increasing the block outlet velocity and decreasing the inlet flow separation. without the catcher cases seen in Figure-18(a), a large flow separation is formed in front of the block inlet, which decreases the block outlet velocity, by adding a catcher with a nondimensional catcher length to block length ratio h/L 0.25, as seen in Figure-18 (b), the airflow started to be redirected toward the building and forced to reduce the flow separation formed at the block inlet. The greater the catcher length is the greater the increase in the velocity at the outlet of the block and the lower the flow separation at the block inlet, as shown in Figure-18 (c), (d), (e), (f), (g) and (h), which represent a catcher with nondimensional catcher length-to-block length ratios h/L of 0.375, 0.5, 0.625, 0.75, 0.875 and 1, respectively.



(a) Without a Catcher
(b) h/L =0.25
(c) h/L =0.375
(d) h/L =0.5
(e) h/L =0.625
(f) h/L =0.75
(g) h/L = 0.875
(h) h/L = 1

Figure-18. Velocity magnitude and stream function of the building block at different nondimensional catcher lengths h/L,

Figure-19 shows the relation between the nondimensional block outlet position and nondimensional block outlet velocity magnitude at nondimensional catcher lengths h/L=0, 0.25, 0.375, 0.5, 0.625, 0.75, 0.875, and 1. From the previous figure, it is concluded that there is a marked increase in the block outlet velocity magnitude by increasing the catcher length until h/L= 0.625. By increasing the catcher length h/L to more than 0.625, the increase in velocity magnitude can be neglected.

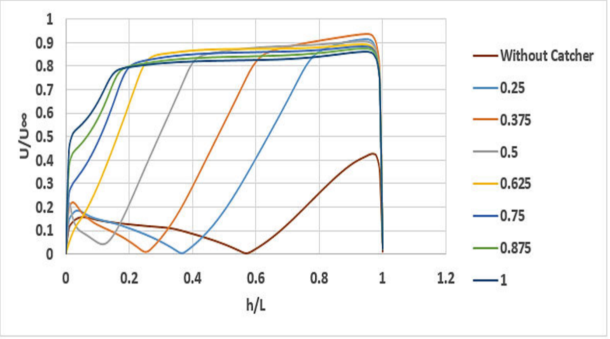


Figure-19. Relation between nondimensional block outlet position and nondimensional block outlet velocity magnitude at nondimensional catcher length h/L (a) 0, (b) 0.25, (c) 0.375, (d) 0.5, (e) 0.625, (f) 0.75, (g) 0.875, and (h) 1.

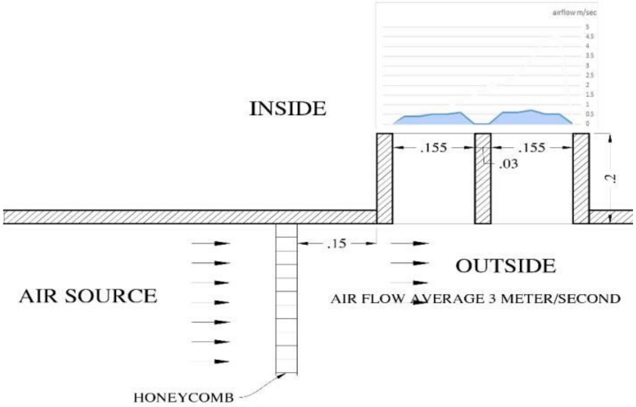


Figure-20. Physical experiment for airflow rate at the outlet of the standard block.

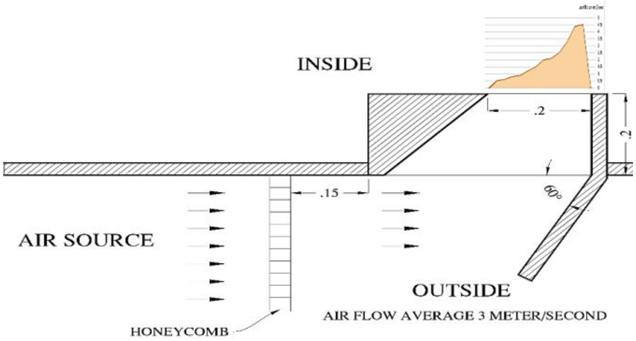


Figure-21. Physical experiment for airflow rate at the outlet of the modified block.

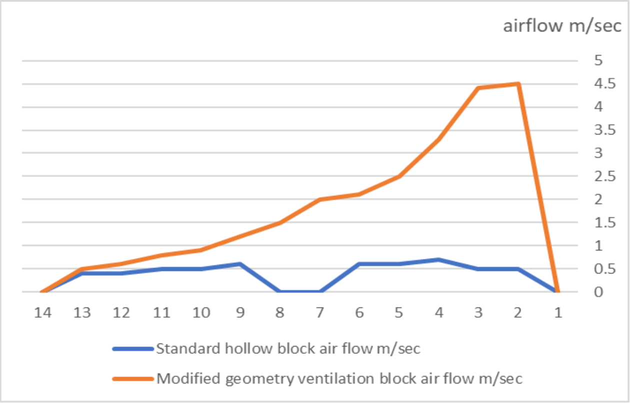


Figure-22. Physical experiment for airflow rate at the outlet of the modified block compared to the standard one.

As per the computer simulation results, the two physical blocks have been built and examined in front of a parallel source of airflow. Figures 20, 21, and 22 show the results of the airflow rate at the outlet of the modified block compared to the standard one. The results showed that the modified block achieved a very high performance and attracted a high speed of airflow at the outlet that reached approximately 4.5 m/sec, while the out-air flow was 3 m/sec Based on the previous results, Figure-23 which illustrates the proposes wall used to direct the wind in the direction of buildings that are not directly exposed to the wind direction. As per the wind rose of Cairo, this wall could be used for the side walls perpendicular to the airflow directions. Accordingly, it could be applied to the North West, North, East, West, East, South West, and South East wall directions.

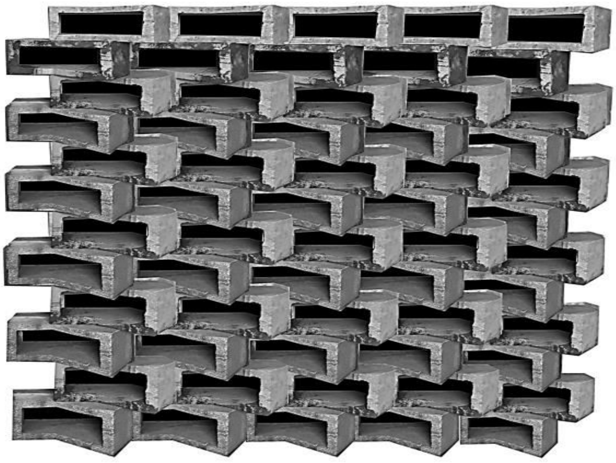


Figure-23. Suggested wall using the final designed block.

5.4 Waste Materials for Green Ventilation Block Production Results

The successful proportions of marble and granite waste substitution for sand and cement were primarily tested. In these mixes, the Styrofoam waste was also used to obtain a green lightweight ventilation block. The tested amounts of Styrofoam in the green mixes ranged between

0.15 and 1 kg in each mix. The marble waste partially substituted the sand by 15% by weight in the mix S15M. The cement was substituted by 5% of the weight of granite waste in the mix C5G. Similarly, granite waste substituted sand by 10% by weight in the mixes S10G. The W/C ratio varied between 0.5-0.65 in the mixes under study, according to the amounts of sludge powder and Styrofoam added as shown in Table (4). The Styrofoam contents significantly affected the block's weight as illustrated in Figure-24.

Table-4. Characteristics and mix proportions by weight.

Mix Code	Type of waste	Mix proportions of 4Bricks+1Block (by weight KG)							Weight	Strength (N/mm2)	Remarks	Cost/1000
		cement	**Sand**	**F. Coarse**	**Granite**	**Marble**	**Styrofoam**	**Water(Lit.)**	**Vent.Blk (KG)**	**Standard > 5.6**		**Vent. Block**
Control St.1	NA	6.39	15.5	12.3	0	0	0.15	3.5	19.41	21.3	Passed	6500
Control St.2	NA	6.39	20.7	8	0	0	1	3.9	15.85	4.35	Failed	
S10G	Granite	6.39	14	12.43	1.5	0	0.15	4.05	19.61	29.68	Passed	6475
S10G	Granite	6.39	18.7	8	2	0	1	4.2	15.3	4.6	Failed	
C5G	Granite	6.07	15.7	12.43	0.32	0	0.15	3.9	19.3	21.58	Passed	6260
C5G	Granite	6.05	20.7	8	0.33	0	1	4.1	16	4.69	Failed	
S15M	Marble	6.39	13.3	12.43	0	2.31	0.15	4.34	20.25	27.57	Passed	6440
S15M	Marble	6.39	17.6	8	0	3.1	1	4.5	15.9	6.87	Passed	6260

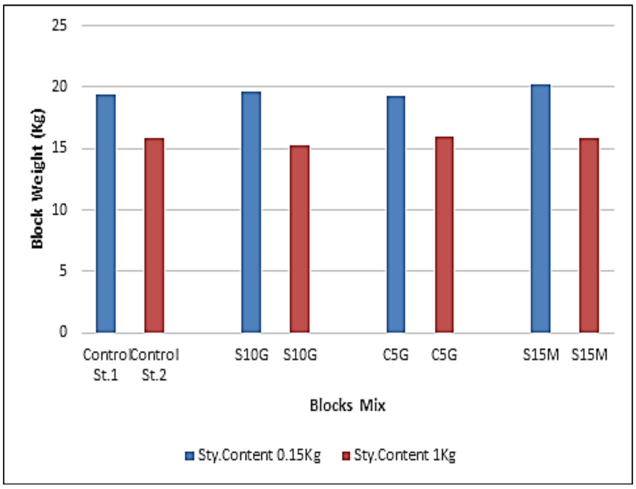


Figure -24. Ventilation Blocks Weight using different Styrofoam Contents.

6. CONCLUSIONS

Different Egyptian climatic regions were studied according to wind direction, speed, and intensity. New Cairo city was chosen for this study as one of the new Egyptian urban models currently having a tremendous increase in the building construction sector. The research revealed that it is preferred to allocate the building corners towards the prevailing wind direction to prevent airflow separation and to magnify the quantities of air along building sides. The results regarding the block design and materials used were concluded as follows:

a) The designed ventilation block has a good performance in ventilation compared with the normal hollow block

b) The ventilation block was designed by adding a catcher fin to the conventional cementitious hollow block of dimensions 20 x 20 x 40 Cm to catch the maximum amount of air.

c) The best block inlet angle is 45°. By increasing the block inlet angle by more than 45°, the block outlet velocity starts to decrease due to the formation of the flow separation in the front of the block inlet.

d) The best catcher angle is at angles 65° to 85°, and the catcher's ability to redirect the airflow is decreased at a catcher angle greater than 85°.

e) The best nondimensional catcher length-to-block length ratio h/L is 0.625. By increasing the catcher length h/L to more than 0.625, the increase in velocity magnitude can be neglected.

f) The physical experiment showed that the modified block achieved a very high performance and attracted a high speed of airflow at the outlet compared to the normal hollow block if a parallel airflow source was applied.

g) The ventilation block can be applied on the North West, North East, West, East, South West, and South East wall directions for slum areas housing in Cairo, Egypt, to improve natural ventilation and create more healthy environments.

h) Using conventional materials, the ventilation block weight was 24.8 Kg which was very difficult to handle as a building unit.

i) Styrofoam, granite, and marble slurry powder wastes were used in the production of the green lightweight ventilation block.

j) Substitution of 15% of sand by marble in the presence of 1 Kg of Styrofoam (S15M) produced a lightweight green ventilation block of weight 15.9 kg.

k) Substitution of 5% of cement by granite in the presence of 0.15 Kg of Styrofoam (C5G) produced a lightweight green ventilation block of weight 19.3 kg.

l) It is recommended to use C5G mix with 150 gm Styrofoam in the production of the green ventilation block to take into consideration the negative impact of the manufacturing process of cement that pollutes the environment.

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