The Windcatcher

An 3D Educational Puzzle

Introduction

- Product Code: PB022
- Material: 3-mm Double-Sided and Coated MDF Fiber
- Number of Pieces: 48
- The Size of Built Replica: 8.5 × 8.5 × 29 (cm)
- Package Size: 21 × 31 × 5 (cm)
- Package Weight: 800 g
- Package Contents: 5 Cut Wooden Sheets/ 2 Rubber Bands / The Manual
- Research and Initial Designing: Mansour Zand Rahimi
- Redesigning, Editing, and Production: Katibeh 3D Puzzles

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The Windcatcher; Technology and Basic Information

Everyone has seen the windcatcher at least one single time. Have you ever wondered how it works?

The windcatcher, wind tower, or Badgeer is a masterpiece of ancient engineering and architecture, even though it might seem like an ordinary building structure. This structure has considerably helped the indoor air ventilation in the old buildings with no modern technologies. As the first task, the windcatcher must conduct the outdoor air streams, which are caused by the wind blowing, into the building. Then, it must cool the indoor air and make it desirable. We will discuss the air conduction method during the replica's setup. But regarding how to cool the indoor air, two essential points playing the leading roles in the function of the windcatchers need to be explained here at the beginning:

1. Our predecessors, especially those who lived in desert regions and always had heat problems due to the hot and dry climates, knew that direct exposure to the sunshine was almost unbearable. They found out that just beside the sunlight, the shade of a wall or building keeps them away from the heat and provides a delightful breeze, too. Therefore, they gradually thought of conducting this cool breeze into their buildings. This idea was the foundation and primary motivation to design and build the windcatcher. But why the shade has a cooler air? Here is a simple experiment to figure out why: by placing a piece of metal, a brick, and a container of water under the sunshine, we will see that after a while, the metal would be hotter than the brick, and the brick would be hotter than the water. It means that the metal and brick have absorbed more heat than the water. The scientific reason for this difference in heat absorbance is that diverse materials exposed to the same amount of sunlight absorb different rates of heat. Scientifically, different materials have various **heat capacities**. The heat capacity of each substance represents the amount of heat that the substance absorbs at a specific time. Thus, in an equal condition and duration, the metal would be hotter than the brick, while the brick would be hotter than the water. Measuring the air heat capacity shows that air has a very slight heat capacity than other

substances (about a quarter of water heat capacity). In simpler terms, from morning and sunrise until almost noon, the air absorbs much less heat than the walls, rooftops, metallic materials, etc. That is why when everything has become warm or even hot, the air is still cool with a temperature lower than other materials in the environment. So, it would be possible to create pleasant indoor conditions by transferring this air inside the buildings. However, it also should be stated that the air heat capacity would be low if the air is dry, as it is in desert areas. It means that the humidity must be as low as possible. Humidity (or, in fact, the tiny water particles in the air) leads to higher absorbance of sunlight heat, increasing the heat capacity of air and firmly reducing the air coolness. Therefore, the windcatcher is not practical in regions with high humidity.

2. Why does blowing wind cool the body's skin?

Everyone has felt the cooled feeling by being exposed to blowing wind, especially when having a little sweat on their body. But why is that? Here is why: blowing wind reduces the air pressure on the skin, releasing the skin moisture, no matter how much it is. The moisture evaporation needs heat. The skin provides this necessary heat and gets cool due to blowing wind and evaporation of moisture. However, the amount of cooling is directly related to the amount of skin moisture and wind speed. Let's cite another example. Consider the wet clothes are spread on the clothesline to be dried. By touching the dried ones, you find them not only dry but also cold. It's because of the evaporation of water droplets or, in fact, the moisture on the surface of clothes. The same happens when a wind stream passes over the water surface, for instance, streams, ponds, pools, and seas. The windblow causes evaporation and, therefore, cooling the water surface. The next windblow will deliver this cool to the adjacent land. The residents of southern ports or islands of Iran have used this feature and have brought the cool air flowing over the sea surface into their buildings by the windcatcher. It means that in addition to desert areas with hot and dry climates, the windcatcher is also practical for coastal southern areas, where the wind blows from the sea towards the beach (however, the windcatcher in these

areas has a simpler structure than in desert ones). We will discuss the application of this coolness due to the evaporation of humidity in the windcatchers of desert areas, as well.

The Effective Factors on Improving Efficiency

Now you know the main role of windcatchers in cooling the indoor atmosphere of buildings. By assembling the windcatcher replicas, you will understand how the windcatchers conduct the cool air in desert areas or sea cool breezes into the buildings. But it's not all of the windcatcher's capabilities. There are some other elements with significant impacts on the cooling of indoor air and, as a result, increasing the efficiency of the windcatchers.

1. Water and Moist Floors and Walls

A water reservoir is usually constructed under the windcatcher (in windcatcher chamber). The air that the windcatcher conducts from outside to the inside of the building first passes over this reservoir and then enters the hall or other rooms. This passage evaporates the water and cools the inner environment as discussed earlier. In some places, however, the windcatcher channels lead directly to the basement. In the past, basements were more often humid. This humidity was positively affecting and helping for more evaporation and cooling of the environment regarding the airflow passing through the vicinity of moist floors and walls. Accordingly, occasionally water-spraying the basement floor (which was usually covered by traditional bricks) could have led to a much more favorable air.

2. Wind Velocity

Another capability of the windcatcher is increasing the wind velocity. If you notice, we can feel the wind inside under the windcatcher while it blows with low or even imperceptible speed outside. Why is that? The volume of air entering each side of the windcatcher is equal to the wind velocity multiplied by the opening surface of that side, which is supposed

to take out the same volume of air from the outlet channels. Since the surface of outlet channels is less than the opening surface , the airspeed must subsequently increase so that the same initial air volume be conducted inside the building.

For example, if the windcatcher has a square-shaped cross-section, and the opening surface of each side has a height 1.5 times its width, the surface of that opening equals 1.5 times the total cross-section of the windcatcher. However, the surface of the adjacent channels is between 1/2 and 1/4 of the windcatcher cross-section, (depending on the windcatcher type). It means that the surface of each side opening is almost 3 to 6 times the surface of the outlet channels of that opening. Therefore, to pass the inlet air volume from inner channels, its speed must be increased to the same extent. Such an increase in airspeed highly helps to more evaporation (either from the body skin, the surface of the water in the reservoir, or moist surfaces of the basement) and then more cooling of the indoor environment or skin. Accordingly, higher heights of windcatcher openings lead to larger opening surfaces and, subsequently, higher wind velocity at the outlet of the windcatcher channels. Moreover, it also should be stated that the increasing wind speed relies on different sizes of openings and cross-sections of windcatchers and is not necessarily equal to the mentioned figures.

3. Materials Type

Using materials with low heat capacities in the structure increases the efficiency of the windcatcher. It shows the popularity of using materials like clay and brick in the windcatcher structure; they have significant heat-insulating properties.

4. Number of Internal Channels and Blades

Although the temperature in arid areas reaches 40 ℃ in the daytime, these areas have cold nights with a temperature around a few degrees. Because of this low temperature, the walls, especially the internal blades and surfaces of the windcatcher, absorb and store lots of chill at night. The next day, the air gets cool by passing over the vicinity of these

inner blades and walls chilled from the night before. That's why more interior surfaces, such as blades and channels, increase the absorbed chill during the night, and it also takes longer during the day to lose their cool.

5. The Height of Windcatcher

The higher height of the windcatcher has three important effects on its efficiency.

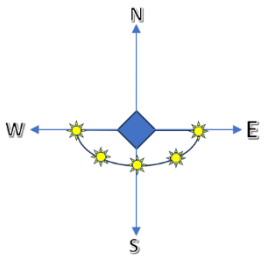
1) The higher the height of the windcatcher from the rooftop, the less heat reaches the adjacent structures from the indirect reflection of sun radiation.

2) The wind has a higher speed at the height due to the lack of structural barriers.

3) Increasing the height of the windcatcher extends its interior surfaces, especially at the stalk section, and makes it possible to absorb and store more chill during the night in the interior surfaces and blades.

6. The Direction of Windcatcher

The direction of the building and placement of the windcatcher are also important and depend on two essential factors: the wind blow direction and the sunlight direction. In one-sided or two-sided windcatchers, the air inlets must be in the direction of the wind. Four-sided windcatchers have no such necessity; they direct the air into the building from any direction it blows. These windcatchers, however, are constructed in the direction of the prevailing wind (mainly the northwest wind). In this situation, only one side of the windcatcher is in the direction of the wind. Therefore, only one side opening catches the whole wind with minimum friction, so the windcatcher would have the highest efficiency. About the sunlight direction, since the geographical position of Iran's desert cities is almost in the orbit of 30 degrees north, the sun does not move in a straight path from east to west. As shown in the figure, the sun moves in a curved direction from east to west with a deviation towards the south.



So, by constructing the windcatcher in the direction of the northwest wind, the northeast and southeast sides are first exposed to sunlight. Next, only the southeast side and after that, the southeast and southwest sides are faced with sunlight. Then, the sun only radiates to the southwest side. Finally, the sunlight hits the southwest and northwest sides. Therefore, the southern sides (southeast and southwest sides) are more exposed to the sunlight than the other ones. The northeast and northwest sides face the sunlight only in the first and last hours of the day, respectively, absorbing less heat than the others. But if the windcatcher is built directly in the north and south direction, its northern side never faces the sunlight. In addition, the efficiency of the windcatcher would be higher obviously in northern windblow. Such a condition is rare, of course.

The Complete Cycle of The Windcatcher Function

Now that we have found out the technology and function of the windcatcher, we are going to find out the steps of a complete working cycle of a windcatcher through the day and night, assuming that its direction is toward the northwest. Most people think the work of a windcatcher starts when the day begins. Well, it's not true. The windcatcher starts its task by night when there is no sunlight radiation and the temperature is low. First, entire surfaces of the windcatcher lose all the heat absorbed during the last day. Then, the windcatcher begins to absorb the nighttime chill, storing it like an accumulator. Therefore, it has a cool body that is completely sensible before sunrise. By raising the sun from the east, the eastern openings are exposed to the sunlight, and its internal air begins to warm little by little. It causes the air to move upward inside the channels adjacent to these openings due to the thermodynamic principles (even without wind blowing). When the indoor air leaves the building through these channels, a pressure reduction at the western openings happens in the opposite direction of sunlight radiation. As a result, the air in their adjacent channels moves downward; a cool air that passes in the vicinity of the surfaces of the windcatcher which were also cooled from the night before leads to a pleasant air

conditioning flow. Due to such conditions, since the early morning, the fresh and cool air enters from western openings, and the warm air leaves through the opposite openings. This condition continues until around noon when the sunlight has its maximum radiation. After a couple of hours, sunlight reaches the western openings, warming their inner air gradually and stopping the inlet air. Because of this, the productivity of the windcatcher decreases slowly from noon onwards until it reaches the minimum.

But what happens if the wind blows? If it blows from the northwest, it's blowing in the opposite direction of the sunlight radiation and to the opening that the sun would not radiate to it until afternoon. Therefore, the wind blowing amplifies the air conditioning flow itself (cool air in and hot air out). Notably, windcatchers show their highest efficiencies in such conditions. If the wind blows from north or west, it still blows mainly to the openings that are not almost against the sunlight direction or receive low radiation. The air conditioning flow is still performed but obviously with lower efficiency. After nightfall, the body and all surfaces of the windcatcher begin to get cold until the morning, as we explained before. By sunrise, the windcatcher starts the next day.

Types and Internal Structure of Windcatchers; General Points

Before assembling the windcatcher replica, we should know more about the types of windcatchers. Based on the sides exposed to the wind, windcatchers are generally divided into different types: one-sided, two-sided, four-sided, six-sided, or eight-sided. The four-sided windcatcher is more common since it can direct the air from any direction into its channels. Six or eight-sided windcatchers also have this ability but they are not so common due to their more complex structures. However, one-sided and two-sided windcatchers only catch the wind that is blowing directly into their inlets.

Regarding the building components, below the roof, the main windcatcher partition is located and is called Ghafaceh which consists of four openings. Each side of this partition is open against air (named here opening) and usually is divided by some blades (called

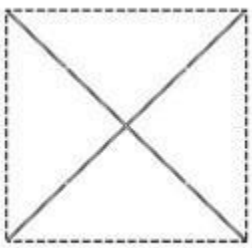
windbreakers) into smaller openings (sometimes called Cheshmeh and here named vents) as the input or output of air. The vents in front of the wind are called windward (Badgeer), while the ones that are opposite to the wind direction are called leeward (Badkhan). Under this partition the stalk partition is located which continues towards the roof, has no way to the outdoor environment, and includes the channels that duct the air into the building. The chimney or Tanoureh is beneath the stalk. The chimney is the distance between the roof of the building and the ceiling of the windcatcher chamber but is not common in all windcatchers. Then, there is the windcatcher chamber. Usually, the water reservoir is inside the chamber . The air enters this chamber through the windcatcher channels. By passing over the water reservoir, it's directed to the other parts of the building or hall by a door or in some buildings, by ducting and channels. Every windcatcher has some internal vertical blades with different tasks. Based on the type of their functionality, they can be divided as below:

- Blades for preventing the wind from wasting or escaping in the opening sections .
- Blades for creating interior channels to direct the air inside and outside and also for separating cool and warm air pathways

The windcatchers can be divided into four types based on the type and position of these blades.

Type 1

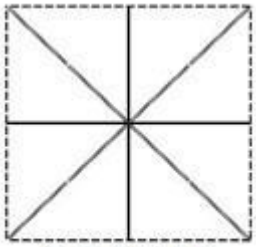
Windcatchers that only have two diagonal vertical blades responsible for preventing the air from escaping through openings and also creating the main internal channels. For example, most of the windcatchers in southern ports of Iran are this type.



Type 1 Section

Type 2

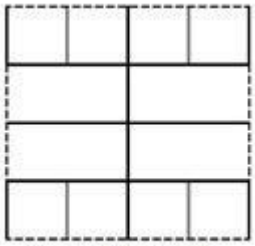
Windcatchers, in addition to vertical diagonal blades, have some longitudinal and transverse vertical blades that divide their inner space into four channels.



Type 2 Section

Type 3

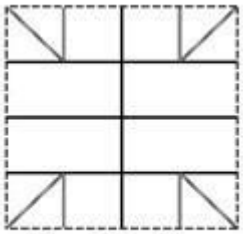
In windcatchers with no diagonal blades, their internal channels are created by some longitudinal and transverse vertical cross blades. However, in this type, some of the air vents have to be inevitably booked or blinded on two opposite sides to prevent the wind from escaping.



Type 3 Section

Type 4

These windcatchers, like windcatchers type 3, have internal channels created by some longitudinal and transverse vertical blades. However, this type of windcatcher has small diagonal blades adjacent to the corners to prevent the wind from escaping.



Type 4 Section

Because of the specific design of this replica, you can assemble samples of each of the four types several times using no glue. Building this replica will show you the structure and function of four-sided windcatchers, and you will also learn about other windcatchers, such as one-sided and two-sided ones, that can be built more easily. Now, let's see how to build a windcatcher replica.

Assembling Replica Type 1

First, you need to detach the windcatcher pieces from the main board. All of these pieces are coded. Try to arrange them using the same codes. Then, assemble the replica based on the following order:

1. First, take the A2 piece and place it on the A1 piece to get their grooves in front of each other. Then, put the tabs of four B pieces (the walls of the water reservoir) inside its central grooves to complete the structure of the windcatcher floor and water reservoir.

2. Put the windcatcher floor on the table. Mount the pieces C1 to C4 on it based on codes in such a way that their patterns and codes face outward (be sure to install them based on numbers from 1 to 4 since every piece has a different size) in such a way that the tab of each piece is set inside a groove of the floor piece. Installing these pieces gives you four walls angled and slightly diagonal than the surface of the floor piece.

3. Get these walls close to each other by hand, and put the two elastic bands (which are inside the box) around the upper and lower parts of the stalk. These elastics must stick the walls together and become entirely paired (in case of not pairing, notice that the bottom tab of all pieces must have been placed thoroughly inside the related groove). Here, you can see that the main body of the windcatcher consists of four walls.

The partition which is on the top includes one opening on each side for entering or exiting air. The stalk partition is located beneath this partition without any way to the outer environment. But if the windcatcher structure were just that, a wind that blew to the opening partition from any direction would have left the windcatcher from the opposite opening without entering the building. So, this opening must be somehow divided internally to catch all the wind to direct it inside the building, along with preventing the wind from escaping. We will discuss it in the next step.

4. First, put the R piece vertically at the top (its groove must be at the top of the piece) and in the direction of the upper surface square diameter. Slide this piece inside and downwards. Push the walls a bit outwards to pass its tabs and move the piece downwards until you hear a clicking sound, showing that it is placed at its position. Next, put the S piece vertically (its groove must be at the bottom of the piece) in the direction of the other diameter of the upper surface square and install it in the same way.

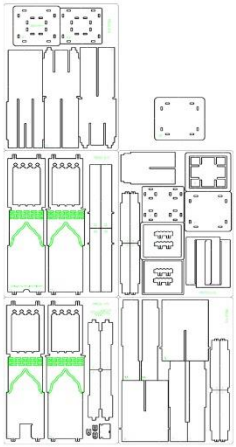
5. Place the L piece from the top on the body and slowly push it downward to set it on the related tabs. Install the M and N pieces on it in the same way.

6. Put the K piece horizontally from the top on the diagonal blades.

7. Install the O piece on the walls. This piece refers to the ceiling. The wall tabs must be placed inside the grooves of this piece. Install the P and W pieces by the same method.

8. Install the door, marked by code E, in its place using its hinges. For this, first, mount the two hinges of the door at a 90-degree angle on its tabs. The door must be placed perpendicularly on the windcatcher walls. Then, set the hinges on the related grooves on the wall and push them gently until they are placed in their positions.

Now, you have built the type 1 windcatcher. As you can see, due to the placement of diagonal blades, the wind, blowing from any direction, has no way to go except to the windcatcher. This type, which has a simpler structure than others, is used in southern ports of Iran, such as Laft or Bushehr, to conduct the cool wind blows on the sea to the building.



Type 1 Replica
Product code: PB022

Detach the pieces from the main board, arrange them based on their codes in the figures, and attach them. There are elastic brands in the package. You can use it for the pairing and matching the walls. This replica does not need glue. Scan the QR code above for more information and training video.

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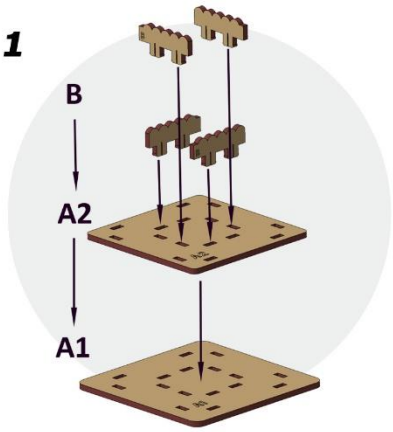

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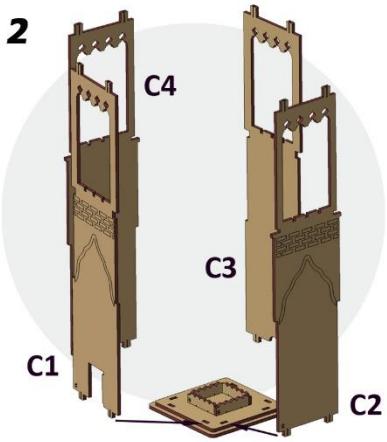

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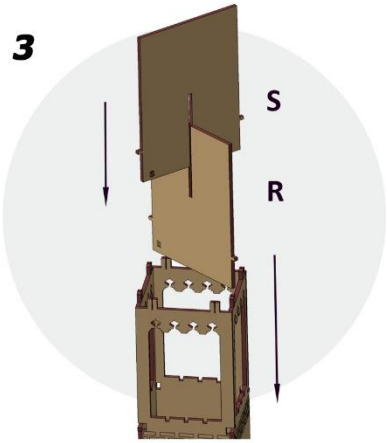

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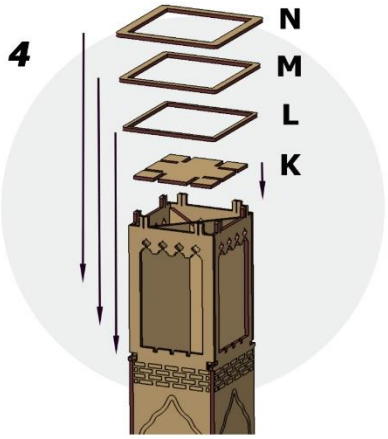

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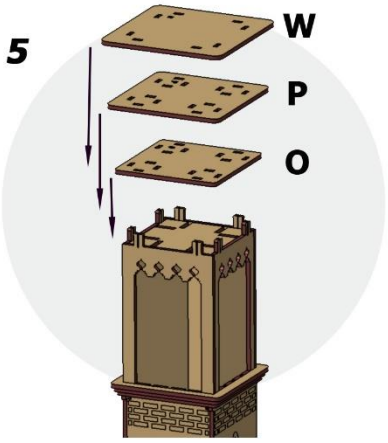

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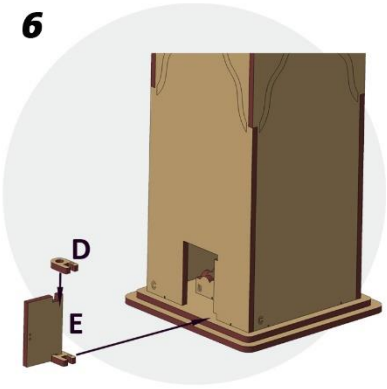

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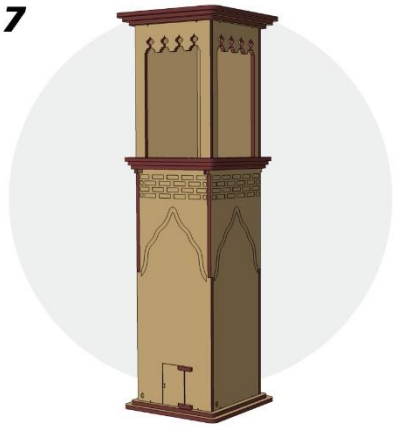


Assembling Replica Type 2

1. Repeat the steps 1 to 4 of the type 1.

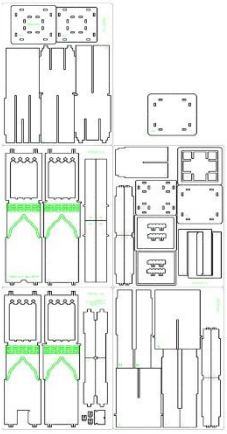
2. In this type, the internal space of the windcatcher is divided by four blades coded by U and T into four equal channels with square sections. For this purpose, first, insert a T piece into the windcatcher from above; its code must be on its bottom section, its lower bump must be towards the intersection of two diametric blades, and its upper bump must be towards one of the walls. Since this piece is wider at the bottom, you need to set it at a 45-degree angle to one of the walls and push its adjacent wall outward a bit to easily insert the piece. Then, turn it around to be perpendicular to the wall. Use your other hand fingers to pair the upper bump in the gap of the middle of the wall opening. Install the other T piece and two U pieces in this way to divide the internal space of the windcatcher into four main channels.

3. Put the K piece horizontally on the roof of the channels.

4. It's time to install the stands, or in other words, windbreakers. In addition to improving the strength of the building, they make the structure beautiful, too. These pieces are coded by V. First, insert one of the V pieces from the top into one of the K piece's grooves. The tab of the V piece must be towards the top of the windcatcher, its code must be downwards, and its longitudinal bump must be towards the wall**.** While you push its adjacent wall outward, slide this piece downward to set its lower tab into the small gap of the wall opening and pairing entirely in its position. Install the other 7 V-pieces in their positions in the same way.

5. Steps 5, 7, and 8 of type 1 replica are the same with this type.

Now, you have completed the type 2 replica. Like the previous one, if you notice the upper section of the windcatcher, you'll see that because of diagonal blades, it makes no difference that wind blows in which direction; it faces one or two openings. While the diagonal blades block the way and prevent the wind from wasting, the wind is directed into the windcatcher inevitably. There are four main channels inside, which can be seen by removing the bottom piece of the structure.



Type 2 Replica
Product code: PB022

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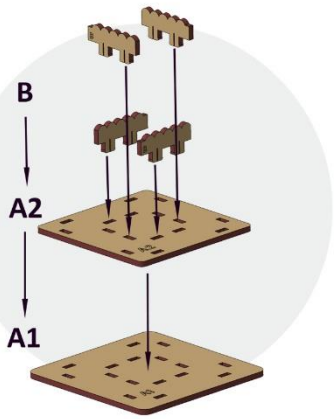

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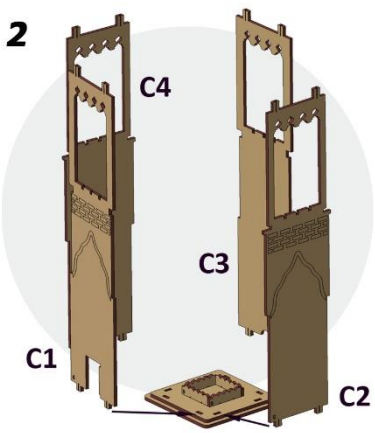

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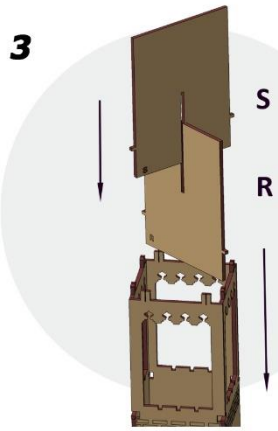

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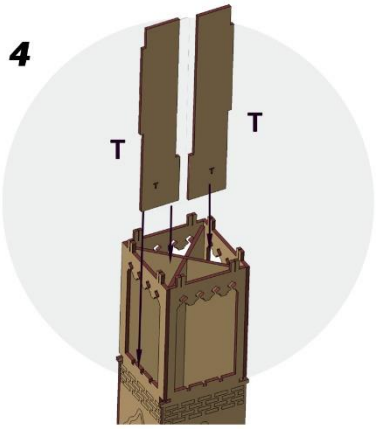

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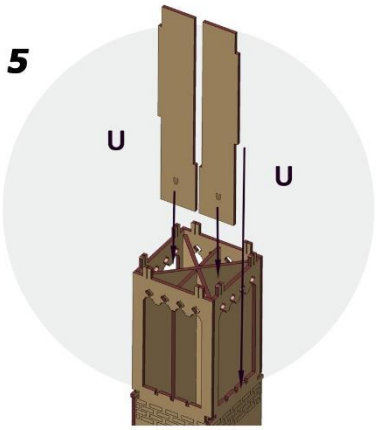

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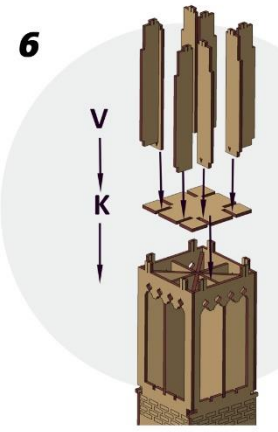

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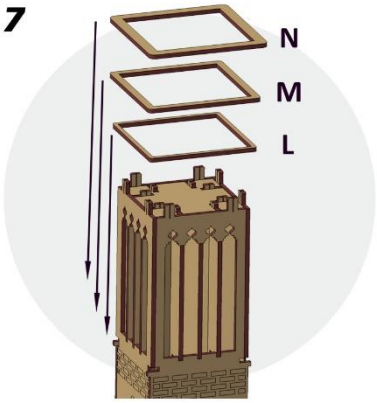

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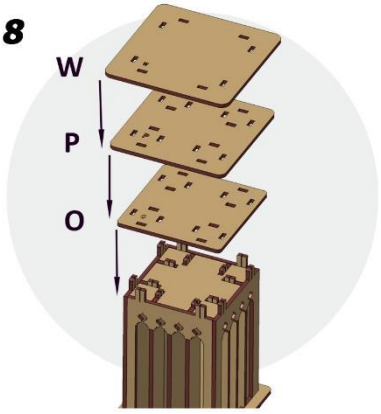

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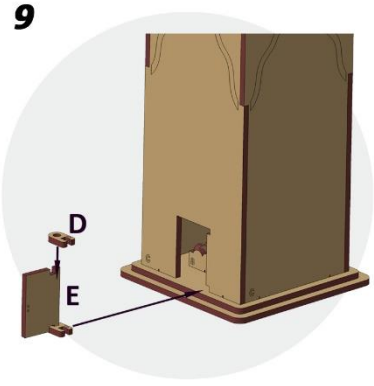


Assembling Replica Type 3

1. Repeat the steps 1 to 3 of the type 1.

2. We first build the internal channels and then wind blockers for this type. Insert the F piece vertically from the top into the windcatcher. Its code must be downwards, and its wider section must be upwards. This piece is going to divide the upper surface in half. The bumps on both sides must be placed in the gaps of the wall openings on both sides. For this purpose, slightly push both walls outwards. Then, you will see that the upper surface of the windcatcher is divided into two equal rectangles.

3. Turn the windcatcher 90 degrees. Insert one of the G pieces vertically from the top into the windcatcher. Its code must be faced downwards, and its wider section must be faced upwards. Its lower groove must get into one of the upper and side grooves of the F piece, and its tabs on both sides, like the previous piece, must be placed in the gaps of wall openings on its both sides. Do the same method for the second piece of G to divide the internal space into 6 channels.

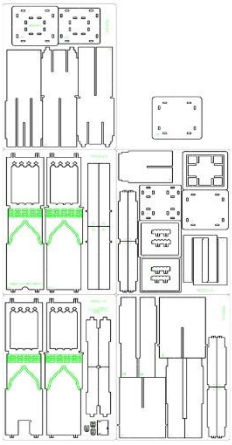
4. Now, you need to install the stands or windbreakers. First, insert the H piece vertically from the top. Its code must be downward, and its wider section must be upward. Its lower grooves must be placed inside the middle grooves of the F piece. Like the previous piece, its tabs from both sides need to be placed in the gap of the wall opening. Then, insert one of the I-pieces vertically into one of the side grooves of the G-pieces while its bump is toward the inside of the windcatcher and its code is downward. Push the wall a little outward to slide this piece downwards to place its lower edge inside the small gap of the wall opening and pair it in its position entirely. Use the same way to set the other three I-pieces inside the grooves of other G-pieces. By installing these pieces, you see that the opening of each side of the windcatcher is divided into four vents for the wind entrance or exitance. But the point here is that the corner vents are open from both sides. Consequently, the wind enters these vents and leaves through the next one. So, it won't

conduct the air inside. So, the paths of wind escaping in each vent must be blocked based on the following order to solve this problem.

5. Insert the J piece from the top and necessarily parallel to the F piece surface attached to one of the main walls into the windcatcher. Its code must be faced downward. But this piece has two internal tabs. To avoid the tabs getting stuck with the G pieces, you need to take the two side arms of this piece with your fingers and pull it a bit outward. Push the walls backward a little, and push the piece attached to the wall gently downward until you hear a clicking sound. This sound assures you that the piece is locked in its position. Do the same for the second piece of J and on the opposite side. By installing these two pieces, you'll see that all the escaping ways for the wind are blocked. This windcatcher catches the wind from any direction it blows, conducting it by its internal channels into the building, like previous windcatchers. The two opposite openings are now divided into four vents with equal depths. The other two openings have two blocked vents. However, the other two vents have two times higher depths than the two previous vents. As a result, all four openings have an equal volume of inlet air.

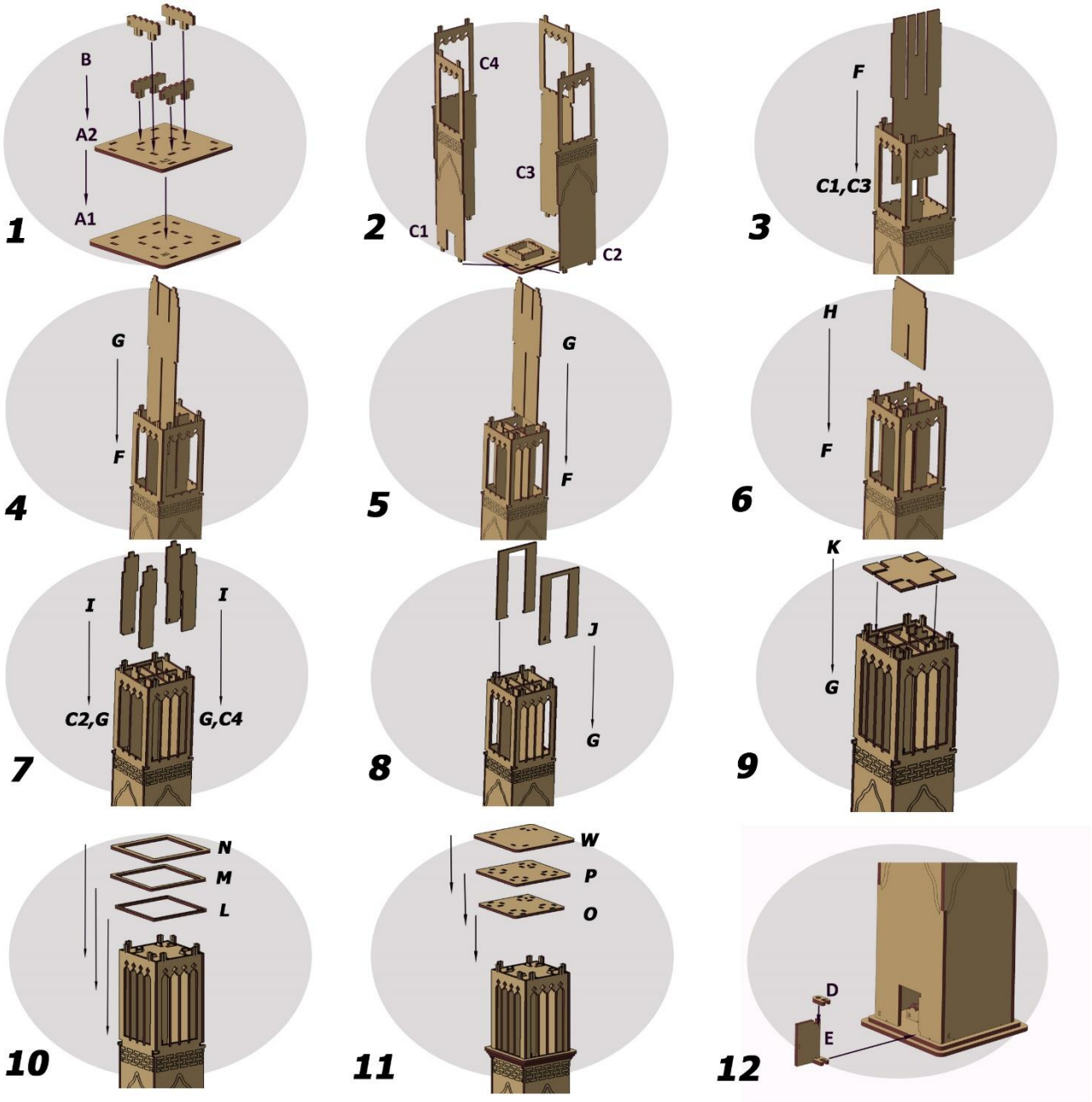
6. Repeat the steps 5, 6, 7, and 8 of type 1.

Now, you have built the type 3 replica.



Type 3 Replica
Product code: PB022

Detach the pieces from the main board, arrange them based on their codes in the figures, and attach them. There are elastic brands in the package. You can use it for the pairing and matching the walls. This replica does not need glue. Scan the QR code above for more information and training video.



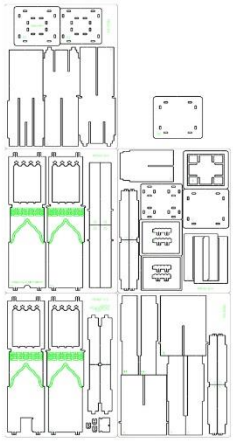
Assembling Replica Type 4

1. Repeat the steps 1 to 4 of type 3.

2. Insert the Q piece from the top, slowly from one of the corners of the windcatcher, in the direction of the diameter of one of the formed squares, to be placed and locked at its position. Its code must be downward, while its little tab must be towards the corner of the windcatcher. For this purpose, you should tilt the two adjacent walls outward a bit. Install the other four pieces in the other corners of the windcatcher in the same way. After installing these four pieces, all escaping paths for wind will be blocked.

3. Repeat the steps 5, 6, 7, and 8 of type 1.

Now you have completed windcatcher type 4.



Type 4 Replica
Product code: PB022

Detach the pieces from the main board, arrange them based on their codes in the figures, and attach them. There are elastic brands in the package. You can use it for the pairing and matching the walls. This replica does not need glue. Scan the QR code above for more information and training video.