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# STANDARD PATENT

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**Name and address of patentee(s):**

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**Title of invention:**

An environment-friendly composite basalt fiber reef base grid suitable for restoration of coral reef substrates and restoration method

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**CN 105660475 B**
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## Abstract

The present invention discloses an environment-friendly composite basalt fiber reef base grid suitable for the restoration of coral reef substrates and a restoration method. It includes a square grid woven from glue-free basalt fiber, and the glue-free basalt fiber is embedded and woven of pure aluminum wires, and the four edges of the grid are fixedly connected with sleeves made of basalt fiber cloth. In the middle of the grid, there are also sleeves made of basalt fiber cloth. The four corners of the grid are equipped with fixed connection holes. The team of the present invention has applied the environment-friendly composite basalt fiber reef base grid to a number of coral reef ecological restoration projects in the tropical coast of the South China Sea and the sea area of islands and reefs. The cumulative application and restoration area has reached 4000 $m^2$ and a good restoration demonstration effect has been achieved.

# An environment-friendly composite basalt fiber reef base grid suitable for restoration of coral reef substrates and restoration method

## Technical field:

The present invention belongs to the field of coral restoration, and specifically relates to an environment-friendly composite basalt fiber reef base grid and restoration method used in coral reef ecological restoration project, which is suitable for the sediments stability and substrates renovation of the sea area types of broken reef rocks, coral gravels and corals debris substrates in coral reef ecological restoration projects of tropical coral reef areas.

## Background:

The coral reef ecosystem is known as the tropical rain forest in the ocean. It is the soul of life and protector of coral islands and reefs. It has important ecological functions of protecting islands and reefs. It can reduce the damage of storms and typhoons, reduce the erosion of ocean currents and waves, replenish lost sand and rocks, stabilize the structure of islands and reefs and create a livable environment. There are more than 200 coral islands, reefs and sandbars in the South China Sea of our country, which is one of the most abundant areas of marine coral reefs in the world. It provides habitats, protected areas, breeding and bait sites for many important organisms, including endangered species, and provides resources such as fisheries and medical biology, and rich and diverse underwater landscapes.

Repairing damaged coral reef ecosystems in the South China Sea islands and reefs and

restoring the ecological service functions of their biological coasts is one of the focuses of safeguarding our country's national rights and interests. Due to the slow growth of hermatypic corals and the slow natural recovery process of coral reefs, it is generally accepted internationally that the management strategies of coral reefs needs to be transformed from passive protection to active recovery, that is, the use of engineering method to restore the environmental conditions of the growth of coral reefs, and biological restoration method to allow the biodiversity of the coral reef ecosystem and the entire ecosystem process to proceed normally, and the overall function of the ecosystem is restored.

During the restoration of the coral reef ecosystem, the substrates of the damaged and collapsed degraded coral reef area is mostly broken coral gravel debris. Gravel and sandy debris rolls and migrates under the drive of water currents, and cannot provide a stable sediments to the adhesion of hermatypic coral larvae, and the rolling of coral debris will also cause mechanical damages such as collisions and frictions to the newborn and artificial bottom sowing hermatypic coral, which is unfavorable to the artificial restoration and natural restoration of the coral reef ecosystem. Reef base grid technology can stabilize, consolidate, and restore the sediments in the damaged coral reef area, and build a large area of restore for corals to adhere and proliferate on the debris substrates which is difficult for them to recover naturally so that to increase the natural supplement adhesion reef base of hermatypic corals, accelerate their natural recovery process, and also provide a good sunstrates foundation for

the proliferation and restoration of other functional biological populations to revive the "coral reef organism" and enter natural recovery status.

**Summary:**

The present invention provides an environment-friendly composite basalt fiber reef base grid suitable for restoration of coral reef substrates and restoration method in view of difficult problems of coral reef ecological restoration such as sediment fragmentation of the collapse of the tropical coral island reef slope reef and the tropical coral island reef lagoon/continental coast coral gravel and debris substrates. It effectively improves the sediment condition of the reef area and increases the environment-friendly reef base grids for ecological restoration to the natural supplement adhesion reef base of hermatypic corals.

The environment-friendly composite basalt fiber reef base grid suitable for restoration of coral reef substrates and restoration method of the present invention includes a square grid woven from glue-free basalt fiber, and the glue-free basalt fiber is embedded and woven of pure aluminum wires, and the four edges of the grid are fixedly connected with sleeves made of basalt fiber cloth. In the middle of the grid, there are also sleeves made of basalt fiber cloth. The four corners of the grid are equipped with fixed connection holes.

Preferably, the glue-free basalt fiber is a glue-free basalt fiber bundle with a diameter of 7-10 mm. The size of a single lattice in the grid is a square of 50~80 mm, and two parallel industrial pure aluminum wires are embedded and woven in each glue-free basalt fiber bundle,

and run up and down on the surface of the basalt fiber bundle at intervals of 5 cm. Fixed connection holes are also provided in the middle of the four sides, and gaskets are provided on the upper and lower sides of all the fixed connection holes (to strengthen and prevent tearing).

Preferably, the industrial pure aluminum wire is $\phi$ 1 mm 1A50 industrial pure aluminum wire, the inner diameter of the sleeve is not less than 25mm which is used for adding supporting and fixing steel bars of $\phi$ 16 mm, and the fixed connection hole is a fixed connection hole with a diameter of 20mm.

The second purpose of the present invention is to provide a method for restoring coral reef substrates, which comprises the following steps:

A grid woven by glue-free basalt fiber is unfolded and fixed on the sea floor of the sea area to be ecologically restored by coral reefs, and pure aluminum wires are embedded and woven in the glue-free basalt fibers.

Preferably, the grid woven by glue-free basalt fiber is a square, and the four edges of the grid are fixedly connected with a sleeve made of basalt fiber cloth. There is also a sleeve made of basalt fiber cloth in the middle of the grid, and fixed connection holes are arranged on the four corners of the grid, thereby forming an environment-friendly composite basalt fiber reef base grid;

A fixed pipe is inserted into each sleeve, so that the grid is fixed longitudinally on the fixed

pipe, and the fixed pipe in the horizontal sleeve expands the grid, and then it is laid flat on the seafloor of the sea area to be ecologically restored.

Preferably, it includes several environment-friendly composite basalt fiber reef base grids, adjacent fixed connection holes of adjacent grids are connected by a splint, and both ends of the splint are provided with holes, the hole at one end of the splint corresponds to the fixing connection hole of a grid and is fixed by inserting fixing bolts, the hole at the other end of the splint corresponds to the fixing connection hole of another adjacent grid, so that several environment-friendly composite basalt fiber reef base grids form a series of grids, and then a fixed pipe is inserted into each sleeve, and each grid is laid flat on the seafloor, and the series of grids are fixed to the seafloor of the sea area to be ecologically restored.

Preferably, fixed connection holes are also provided in the middle of the four sides, and gaskets are provided on the upper and lower sides of all the fixed connection holes (to strengthen and prevent tearing).

Preferably, the fixing bolts are T-shaped fixing bolts, and the longitudinal direction of the T-shaped is used as the fixing bolts, which presses on the sleeve laterally.

Basalt fiber is mostly used for surface anti-corrosion and structural reinforcement in marine engineering. Although basalt fiber itself is processed by melting natural basalt, it is an environment-friendly engineering material, but in actual use, it is necessary to add at least 15% of epoxy resin materials into the basalt fiber in order to achieve the required mechanical

and chemical properties, which significantly affects its environmental friendliness. Epoxy resin materials are not added into the composite basalt fiber of the present invention during the production process of the basalt fiber, but pure aluminum wires are added into the basalt fiber to increase the mechanical performance and environmental friendliness, and can also improve the adsorption rate of coral larvae. The environment-friendly composite basalt fiber reef base grid suitable for the restoration of coral reef substrates of the present invention completely uses glue-free basalt fiber bundles as the main material, embedded and woven pure aluminum wire as the ecological and mechanical functional material, and the edge banding reinforcement material is basalt fiber cloth, high-strength cotton thread and stainless steel gaskets, all of the above materials are environment-friendly natural materials, or can be naturally degraded in use, and the available data indicates that they have no negative impact on marine ecosystem.

The composite basalt fiber reef base grid is used to physically stabilize the sediments, fix and restrict the range of coral bone fragments and debris moving with the waves, which can effectively restrict the migration of debris in the disposed area, reduce the impact of water scour on the sediments, and has a good stable effects on the substrates of the restoration area. The sediments of natural debris and gravel reef area can achieve preliminary natural consolidation in 2 to 3 years after artificial stabilization, and the debris can be solidified in the reef through biological cementation. Therefore, to balance the ecological effect, mechanical

performance and grid service life, we choose glue-free basalt fiber and pure aluminum wire as the main grid materials. The actual selected width of the fiber bundle should be adjusted according to the particle size of the sediments debris and the hydrodynamic conditions in the sea area of the ecological restoration project. In sea areas with small particle size of sediments debris or high environmental hydrodynamic strength, wider basalt fiber bundles should be used to make reef base grids. The side length of a single lattice should be 50~80 mm. The specific side length should be adjusted according to the size and distribution of the main benthic organisms and reef fishes in the restoration area. While ensuring the stability of the sediments, the permeability of the sediments should also be ensured to allow most reef-dwelling organisms to travel between the sediments and the water body freely.

The environment-friendly composite basalt fiber reef base grid of the present invention has good flexibility and bending ductility. It can be completely folded. Each grid can be packaged into a regular and independent piece of about 70*70*20 cm for transportation and storage. It does not take up extra space and is convenient for stacking and transportation. Compared with ordinary metal and plastic grids/mesh which can only be stacked or rolled into a cylindrical shape, it has obvious advantages and is more suitable for making large-size reef base grids. This feature is also more conducive to the unfolding and paving of the composite basalt fiber reef base grid under water. A diver can easily carry two grids to the sediments for operations. The surfaces of coral gravels and debris sediments have a large number of small reef

undulations and sand pit recessed structures. Ordinary metal and plastic grids/mesh are difficult to adhere to the sediments during unfolding and paving due to their poor flexibility and plasticity. The restriction and stabilization effect on the debris will be relatively poor, and when coral larvae are adhesion to it, the grid is suspended on the sediments, which makes the coral cannot be connected and solidified to the sediments. After the coral grows to a certain size, it will easily fall off and die under the influence of the dynamic environment, so the effect of restoration will be weakened. In addition, ordinary metal and plastic grids/mesh are affected by the mechanical properties of the materials, it is difficult to pave and fix underwater, and the plastic grid/mesh must be removed after use, which restricts the large-scale application of existing reef base grid technology in ecological restoration. The environment-friendly composite basalt fiber reef base grid has good flexibility, plasticity and bending ductility, it can better fit the concave-convex structure of the sediments surface in restoration applications, effectively restricting the rolling migration of gravel and sandy debris. And it is conducive to the coral larvae adhesion to the reef base grid to consolidate on the sediments, and accelerate the fusion of the reef base grid and the sediments and the natural recovery process of the sediments.

The team of the present invention has applied the environment-friendly composite basalt fiber reef base grid to a number of coral reef ecological restoration projects in the tropical coast and islands and reefs of the South China Sea. The cumulative application and restoration area has

reached 4000 $m^2$ and a good restoration demonstration effect has been achieved.

**Description of the drawings:**

Figure 1 is a diagram of the grid-like composite basalt fiber of the present invention;

Figure 2 is a diagram of cutaway view of the glue-free basalt fiber bundle;

Figure 3 is a structural diagram of an environment-friendly composite basalt fiber reef base grid suitable for restoration of coral reef substrates in Embodiment 3;

Among them, 1. Glue-free basalt fiber bundle; 2. Industrial pure aluminum wire; 3. Sleeve; 4. Fixed connection hole; 5. Stainless steel splint; 6. Hole.

**Detailed Description of Embodiments**

The following embodiments are to further illustrate the present invention, but not to limit the present invention.

**Embodiment 1:**

Glue basalt fiber (diameter 10mm) added with 20% (mass fraction) of epoxy resin, composite basalt fiber (that is, two parallel $\phi$ 1 mm 1A50 industrial pure aluminum wires 2 are embedded and woven in glue-free basalt fiber bundle of diameter 10mm, and ran up and down on the surface of the basalt fiber bundle at intervals of 5 cm, as shown in Figure 1 and Figure 2), cement board, plastic board and aluminum alloy board were used as materials. The glue basalt fiber or composite basalt fiber was woven into a grid, and the pore size of the grid was 5 cm.

The above-mentioned experimental materials were cut into the size of 15cm*15cm. The cement board was soaked in the circulating seawater tank for 56 days in advance, and other materials were soaked for 25 days. Planula larvae of pocillopora damicornis was used in the experimental coral. After counting, they were placed in 3 L glass beakers for adhesion culture. Each glass beaker contained a kind of experimental material. All experimental group beakers were bathed in the same water tank system to ensure consistent temperature, the adhesion rates of larvae of different materials were calculated after 2 days.

The results are shown in Table 1:

Table 1

| Experimental materials | Floating Number | Number adhered to experimental materials | Number adhered to glass beaker wall |
|---|---|---|---|
| Glue basalt fiber | 47 | 4 | 1 |
| Glue basalt fiber | 42 | 2 | 2 |
| Glue basalt fiber | 42 | 1 | 1 |
| Glue basalt fiber | 39 | 5 | 4 |
| Glue basalt fiber | 43 | 3 | 1 |
| Composite basalt fiber | 45 | 10 | 2 |
| Composite basalt fiber | 45 | 16 | 1 |
| Composite basalt fiber | 46 | 17 | 1 |
| Composite basalt fiber | 46 | 12 | 0 |
| Composite basalt fiber | 49 | 9 | 0 |
| Cement board | 47 | 9 | 1 |
| Cement board | 51 | 6 | 2 |
| Cement board | 49 | 4 | 1 |

| | | | |
|---|---|---|---|
| Cement board | 43 | 12 | 1 |
| Cement board | 44 | 7 | 2 |
| Plastic board | 48 | 1 | 3 |
| Plastic board | 47 | 3 | 1 |
| Plastic board | 49 | 1 | 1 |
| Plastic board | 42 | 6 | 1 |
| Plastic board | 47 | 1 | 2 |
| Aluminum alloy board | 42 | 7 | 1 |
| Aluminum alloy board | 43 | 9 | 0 |
| Aluminum alloy board | 43 | 14 | 1 |
| Aluminum alloy board | 48 | 8 | 2 |
| Aluminum alloy board | 45 | 8 | 2 |

The composite basalt fiber had excellent ecological performance compared with the existing substrates stability materials. In the comparative experiment of larval adhesion of hermatypic corals, the comparative experiment material was soaked in natural seawater to form a biofilm on the surface of the material, the adhesion rate of larvae and the selection of adhension materials of planula larvae of the glue-free basalt fiber grid (composite basalt fiber), the conventional 20% epoxy resin basalt fiber grid (glue basalt fiber), plastic board, ordinary portland cement board and aluminum alloy board were compared. Compared with current conventional sediments stability materials, the coral larvae showed a clear preference to the adhesion sediments made of glue-free basalt fiber material among the water tank with 5 materials. The order of the number of adhesion larvae per unit area from high to low: glue-free basalt fiber (composite basalt fiber)> aluminum alloy> portland cement board> 20%

epoxy resin basalt fiber (glue basalt fiber)> plastic; in the single material adhesion experiment, the adhesion rate of larvae of glue-free basalt fiber was 50% higher than that of aluminum alloy. Metallic materials had a significant effect of induction adhesion to some coral larvae. For example, the induction effect of pioneer species such as Pocillopora was very obvious. The rapid addition of pioneer species in damaged ecosystems was very important for the recovery of coral populations. Therefore, to balance the induction effect of reef base grid larvae, service life and the mechanical properties of materials, pure aluminum wire was selected as a component of the composite fiber bundle. Compared with the iron wire and aluminum alloy, the corrosion rate of pure aluminum wire was intermediate, and the metal induction effect of coral larvae could also be maintained, and it had good plasticity, conductivity and bending ductility, which was conducive to the underwater laying of the grid and the subsequent ecological restoration operation requirements.

**Embodiment 2:**

As shown in Figure 1, Figure 2 and Figure 3, the environment-friendly composite basalt fiber reef base grid suitable for coral reef substrates restoration of this embodiment included a square (3*3m) grid woven by glue-free basalt fiber bundle 1 with a diameter of 10mm, and the single lattice in the grid was a square with a side length of 80 mm. Two parallel $\phi$ 1 mm 1A50 industrial pure aluminum wires 2 were embedded and woven in each glue-free basalt fiber bundle 1, and ran up and down on the surface of the basalt fiber bundle at intervals of 5

cm. The grid was folded inward along the four sides and folded with basalt fiber cloth and sewn into a sleeve shape to form sleeve 3. The inner diameter of the sleeve was not less than 25 mm which is used for adding supporting and fixing steel bars (fixed pipe) of $\phi$ 16 mm. One side of the middle of the grid also needed to be sewn into a sleeve 3 by basalt fiber cloth. Sleeve 3 was fixed in the middle of the grid and used to add $\phi$ 16 mm supporting and fixing steel bars (fixed pipe). All the sewing threads of the sleeve were processed with high-strength cotton thread. The four corners of the grid and the middle of each side had a fixed connection hole 4 of $\phi$ 20 mm and were reinforced with a 304 stainless steel gasket to prevent tearing. That was, each reef base grid had a total of 8 fixed connection holes. An environment-friendly composite basalt fiber reef base grid suitable for restoration of coral reef substrates was obtained.

Several environment-friendly composite basalt fiber reef base grids suitable for the restoration of coral reef substrates were connected. Specifically, the adjacent fixed connection holes of adjacent grids were connected by stainless steel splints 5, specifically there are two 304 stainless steel splints with a length of 30 cm, a width of 50 mm, a thickness of 4 mm and provided with hole 6 at both ends, are on the upper and lower sides of adjacent fixed connection holes respectively. The hole at one end clamp the fixed connection hole of the grid and lock them with 316 stainless steel bolts. One end used the same operation to complete the connection between adjacent grids, so that the grids formed a series of grids, and then a fixed

pipe (2 m $\phi$ 16 mm steel bar) was inserted into each sleeve to make the grid unfold and fix. The grid was placed flat on the seafloor, and the series of grids were fixed on the seafloor in the sea area to be ecologically restored by the coral reef.

## Claims

1. An environment-friendly composite basalt fiber reef base grid suitable for the restoration of coral reef substrates, characterized in that, it includes a square grid woven from glue-free basalt fiber, and the glue-free basalt fiber is embedded and woven of pure aluminum wires, and the four edges of the grid are fixedly connected with sleeves made of basalt fiber cloth. In the middle of the grid, there are also sleeves made of basalt fiber cloth. The four corners of the grid are equipped with fixed connection holes.

2. The environment-friendly composite basalt fiber reef base grid suitable for the restoration of coral reef substrates of claim 1, characterized in that, the glue-free basalt fiber is a glue-free basalt fiber bundle with a diameter of 7-10 mm. The size of a single lattice in the grid is a square of 50~80 mm, and two parallel industrial pure aluminum wires are embedded and woven in each glue-free basalt fiber bundle, and run up and down on the surface of the basalt fiber bundle at intervals of 5 cm. Fixed connection holes are also provided in the middle of the four sides, and gaskets are provided on the upper and lower sides of all the fixed connection holes.

3. The environment-friendly composite basalt fiber reef base grid suitable for the restoration of coral reef substrates of claim 1, characterized in that, the industrial pure aluminum wire is $\phi$ 1 mm 1A50 industrial pure aluminum wire, so the inner diameter of the sleeve is not less than 25mm which is used for adding supporting and fixing steel

bars of $\phi$ 16 mm, and the fixed connection hole is a fixed connection hole with a diameter of 20mm.

4. A method for restoring coral reef substrates, characterized in that, it comprises the following steps:

A grid woven by glue-free basalt fiber is unfolded and fixed on the seafloor of the sea area to be ecologically restored by coral reefs, and pure aluminum wires are embedded and woven in the glue-free basalt fibers.

5. The method for restoring coral reef substratesof claim 4, characterized in that, the grid woven by glue-free basalt fiber is a square, and the four edges of the grid are fixedly connected with a sleeve made of basalt fiber cloth. There is also a sleeve made of basalt fiber cloth in the middle, and fixed connection holes are arranged on the four corners of the grid, thereby forming an environment-friendly composite basalt fiber reef base grid;

A fixed pipe is inserted into each sleeve, so that the vertical grid is fixed longitudinally on the fixed pipe, and the fixed pipe in the horizontal sleeve expands the grid, and then it is laid flat on the seafloor of the sea area to be ecologically restored.

6. The method for restoring coral reef substrates of claim 4, characterized in that, it includes several environment-friendly composite basalt fiber reef base grids, adjacent fixed connection holes of adjacent grids are connected by a splint, and both ends of the splint are provided with holes, the hole at one end of the splint corresponds to the fixing

connection hole of a grid and is fixed by inserting fixing bolts, the hole at the other end of the splint corresponds to the fixing connection hole of another adjacent grid, so that several environment-friendly composite basalt fiber reef base grids form a series of grids, and then a fixed pipe is inserted into each sleeve, and each grid is laid flat on the seafloor, and the series of grids are fixed to the seafloor of the sea area to be ecologically restored.

7. The method for restoring coral reef substrates of claim 5, characterized in that, fixed connection holes are also provided in the middle of the four sides, and gaskets are provided on the upper and lower sides of all the fixed connection holes.

8. The method for restoring coral reef substrates of claim 6, characterized in that, the fixing bolts are T-shaped fixing bolts, and the longitudinal direction of the T-shaped is used as the fixing bolts, which presses on the sleeve laterally.

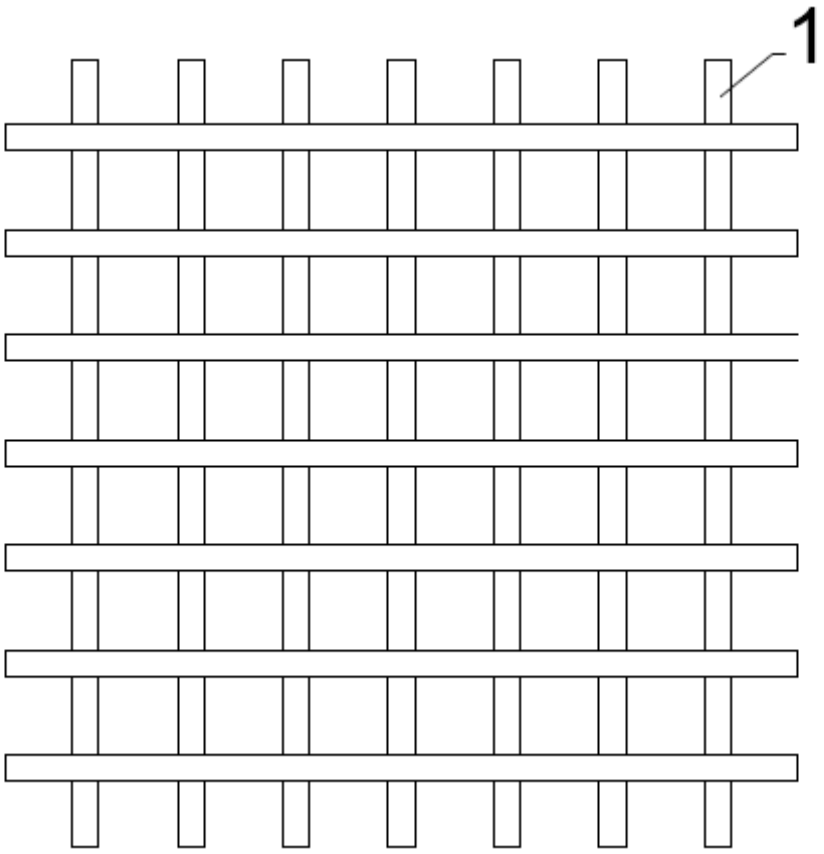


**Figure 1**

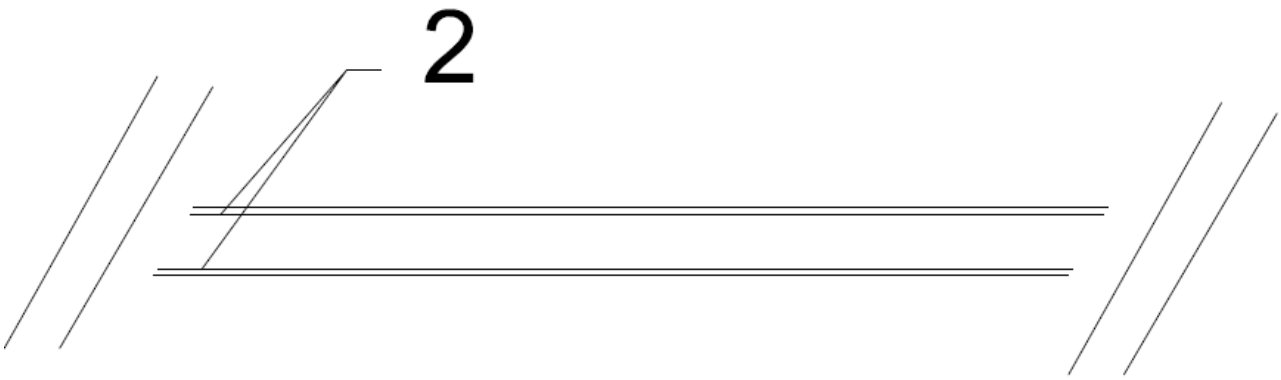


**Figure 2**

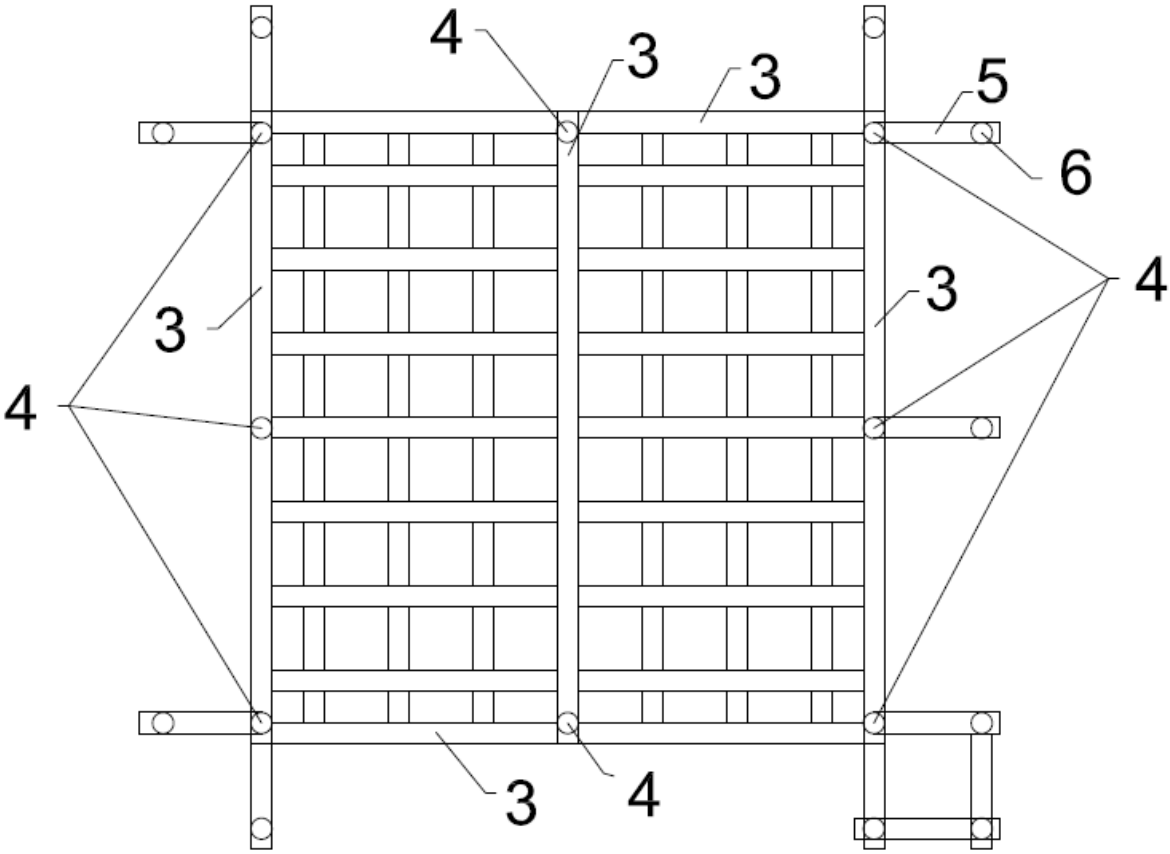


**Figure 3**