A new method for carbon sequestration in coastal area

Y H Li[1,4], L Q Xie[2] and T-C Su[3]

[1]School of Naval Architecture, Ocean and Civil Engineering, Shanghai Jiaotong University, P R China
[2]Department of Hydraulic Engineering, Tongji University, P R China
[3]Department of Ocean and Mechanical Engineering, Florida Atlantic University, USA

E-mail: yyhli@sjtu.edu.cn

Abstract. An artificial Stony Coral Reef Building System *(SCRBS)* was proposed as a new method for carbon sequestration in coastal area. The *SCRBS* is a proprietary technology developed by the authors of the present study. There are three steps of this method: the wave energy was transferred into marine current energy; electric power was generated from this current energy; and the artificial stony coral reef was created by the synthetic action of dissolved carbon dioxide and calcium ion under the promoting effect of low electric current in the seawater. In the process of creating stony coral reef, the carbon dioxide both in the atmosphere above sea surface and in the seawater was absorbed and sequestrated or semi-sequestrated. This method was validated in indoor experiments under heavy polluted environmental conditions. The results show it is highly efficient in reduction of carbon dioxide content in coastal environments.

1. Introduction

In the modern society, the fast developing economy and industry make huge emission of carbon dioxide in coastal areas, causing rapid rise of carbon concentration in atmosphere and seawater. As a result, the issues of greenhouse effect and other heavy pollution problems are becoming increasingly serious, which are increasing people's health burden, threatening mankind survival, and challenging the ecological system on earth. Therefore, how to reduce the concentration of carbon dioxide to improve environment is an urgent concern for global engineers and researchers [1-3].

The carbon sequestration method has been found an efficient way for the capture and sealing of carbon dioxide. In recent years, various carbon sequestration methods have been developed, which include physical, chemical, ecological and artificial ecological methods. Among these methods, physical and chemical methods usually affect the balance of ecological system; ecological method usually need long time to play its advantage; the artificial ecological method is usually considered high efficient and benefit to environment.

In the present study, a new efficient method of artificial ecological measure for carbon sequestration was proposed and validated in an indoor physical experiment. By this method, a new stony coral building technique was applied to absorb, transform and sequestrate the carbon element in coastal seawater. The mechanism of this technique is to transfer the wave energy into marine current energy, then transfer the current energy into electric power, which provides low electric current in the seawater. The low electric current dissolves the carbon dioxide into carbon element, and dissolves the calcium synthesis into calcium ion, and finally promotes the synthesis of these two elements to build

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artificial stony coral in the seawater.

2. Experimental setup of stony coral reef building system

The sketch of the experimental model of the Stony Coral Reef Building System *(SCRBS)* is shown in figure 1. The *SCRBS* composes of three main sections, i.e., the wave-current energy transforming section, the electric power generating section, and the stony coral building section. The device of the wave-current energy transforming section is a tilt-stair shape breakwater (figure 2). The tilt ladders break the incident wave and guide the current of the broken wave into its lower end, thereby transforming the wave energy into marine current energy. The dimensions of this breakwater model are shown in figure 2. The height of the back wall $H = 50$ cm; the length $L = 130$ cm; and the width, $W = 40$ cm. The upright section of the breakwater composes of five tilt stairs. The width of each stair $w = 8$ cm; the height $h = 5$ cm; and the length $l = 100$ cm.

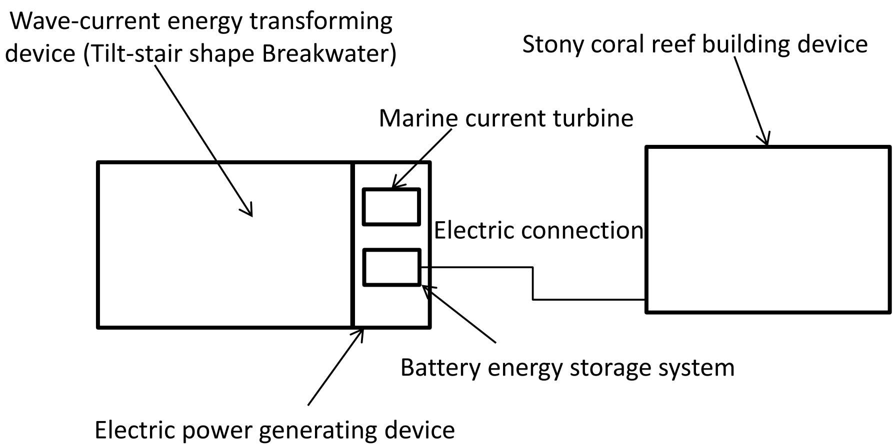

Figure 1. Sketch of stony coral reef building system.

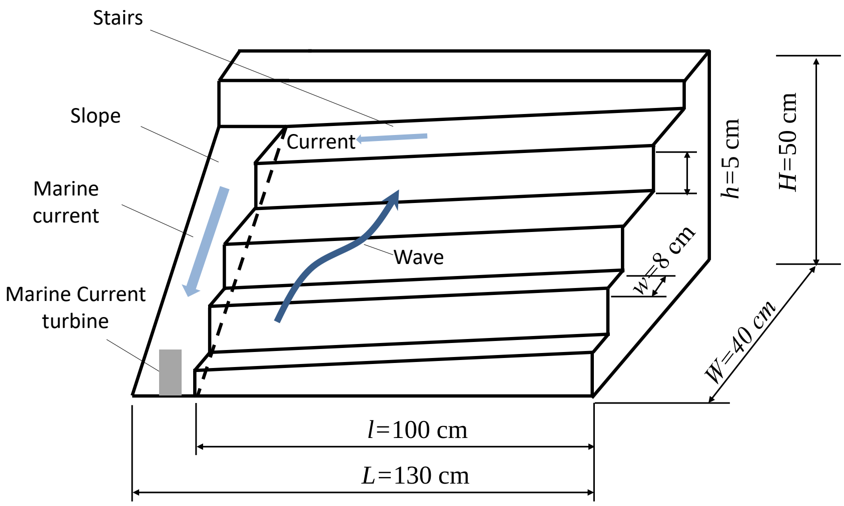

Figure 2. Dimensions of tilt stair shape breakwater.

The electric power generation section composes of a marine current turbine and a battery energy storage system (figure 1). They are installed at the lower end of the tilt-stair shape breakwater. The electric power is generated by the marine current turbine and stored in the battery, then put out through a rectifier transformer. The output voltage is 1.2 V. The marine current turbine and the battery energy storage system were covered in two steel boxes, separately.

The stony coral reef building section composes of three pairs of plate electrodes (figure 3) which are connected to the battery. The anodes and cathodes are both made of inert materials. The anode plates are made of graphite materials, and the cathode plates are made of activated carbon fibre felts. Each pair of electrode plates were set up vertically parallel, and the distance between each pair was 5 cm. This distance was chosen to allow the ionized atom to move between the electrode pair fluently. The distance between two pairs of the plate electrodes was 15 cm. The electrons attached on the anode plate set off a chemical reaction with carbon dioxides and calcium ions, creating artificial stony coral on the cathode plate, forming coral reefs. Thereby the carbon element was sequestrated semi-permanently. In the process of the creation of artificial coral reefs, the carbon dioxide dissolved in the seawater was continually absorbed and reduced. And the carbon dioxide in the atmosphere above the seawater was fluxed into the seawater due to the presence of its concentration grade. As a result, the issue of carbon pollution in coastal area can be solved through the set of Stony Coral Reef Building System proposed in the present study.

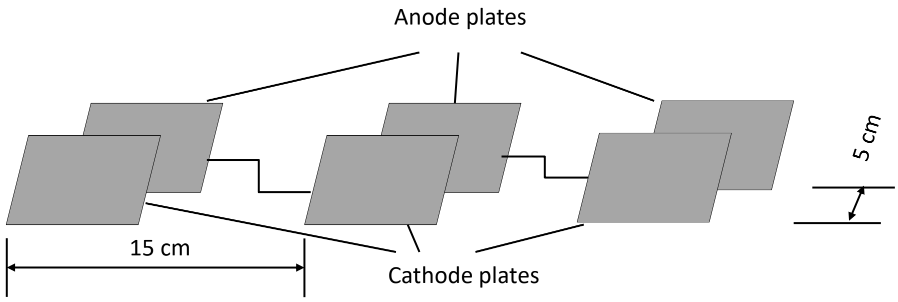

Figure 3. Sketch of stony coral reef building system.

3. Experimental setup of wave condition, carbon dioxide content and seawater

The experiments were conducted in an indoor wave basin of 12 m long, 8 m wide and 1.2 m high. Regular wave of wave heights H_w=0.03 m, wave frequency $f_w = 0.48$ Hz, and incident wave angle θ=45° was set up in the experiments. The incident angle of wave refers to the including angle between the direction of the incident wave and the low end of the stairs of the breakwater. Two initial carbon dioxide contents in seawater (C_{sea}=3610 ppmv and 2683 ppmv for Test A and Test B, respectively) and two corresponding initial carbon dioxide contents in atmosphere (C_{air}=0.13% and 0.086% for Test A and Test B, respectively) were set up under this wave condition. These carbon dioxide contents were set up to build heavy polluted environments.

The seawater was modelled by tap water. The chlorine ion was removed before experiments. The initial concentration of calcium ion in the water was 0.41 g/kg. The calcium ion containing solution was added every 4 hours to maintain its concentration in the range [0.26-0.55] g/kg. The initial conductivity of experimental water was 1600 μS/cm. These two values were set up to model the natural seawater environment.

Each experiment was conducted for 4 days. The experimental wave ran 3 times per hour and 10 min for each time. The carbon dioxide content in the atmosphere was sampled at 0.6 m above the seawater surface. The carbon dioxide contents in the atmosphere and seawater and the PH value of seawater were sampled every 8 hours.

4. Results

For two heavy polluted environmental conditions, the carbon dioxide contents in both atmosphere and seawater are reduced significantly after 4 days (figures 4 and 5), and they both meet the requirement of human health, that is, $C_{air} < 0.045\%$ and $C_{sea} < 800$ ppmv. Figure 4 indicates the carbon dioxide content in atmosphere decreases rapidly when $C_{air} > 0.45\%$; it decreases slower when $C_{air} \leq 0.45\%$.

For the heavier polluted condition (figure 4(a)), C_{air} decreases rapidly in the first 64 hours when $C_{air} > 0.45\%$, and then exceeding this critical value, it decreases gradually in the last 32 hours. For the lighter polluted condition (figure 4(b)), C_{air} decreases rapidly in the first 24 hours when $C_{air} > 0.45\%$, and then decreases gradually in next 72 hours.

Figure 5 indicates the carbon dioxide content in seawater decreases rapidly when $C_{sea} > 1100$ ppmv; it decreases slower when C_{sea} <1100 ppmv. For the heavier polluted condition (figure 5(a)), C_{sea} decreases rapidly in the first 56 hours when C_{sea} >1100 ppmv; when C_{sea} exceeds this critical value, it decreases gradually in the last 36 hours. For the lighter polluted condition (figure 5(b)), C_{sea} decreases rapidly in the first 16 hours when C_{air} >1100 ppmv, and then decreases gradually in next 80 hours.

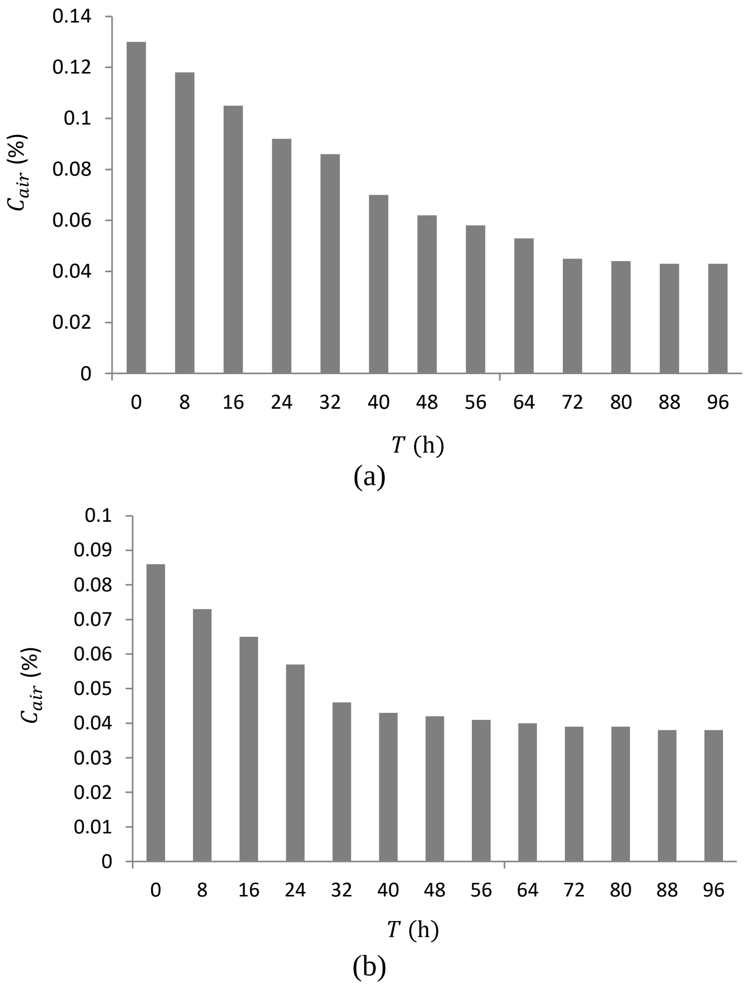

Figure 4. (a) Carbon dioxide contents in atmosphere (test A) and (b) Carbon dioxide contents in atmosphere (test B).

5. Conclusions

A new method for carbon sequestration in coastal seawater and atmosphere was proposed and experimentally studied. With this method, the wave energy is transformed into marine current energy, and then transformed into electric power. This electric power provides low electric current to promote the chemical composition of stony coral reef in coastal water. Thereby the exceeding carbon dioxide in the sea water is sequestrated or semi-sequestrated in the coral reef. The carbon dioxide in atmosphere is fluxed into seawater continually. Two heavy carbon dioxide polluted coastal environments were tested in indoor experiments. The results show this method is highly efficient in the reduction of coastal carbon dioxide contents in both atmosphere and seawater.

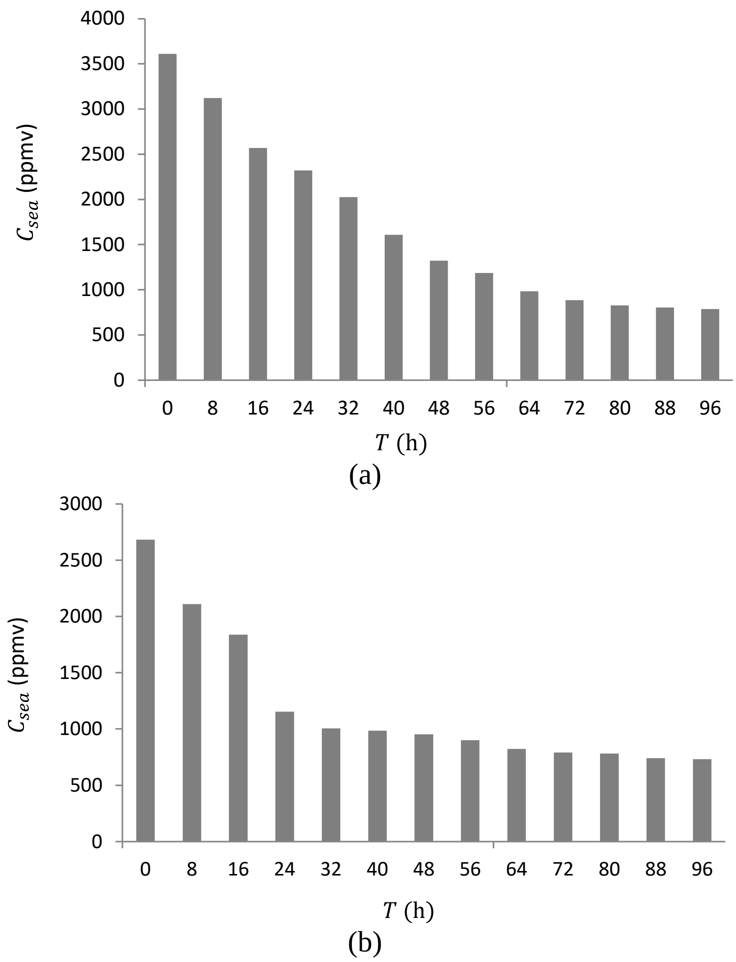

Figure 5. (a) Carbon dioxide contents in seawater (test A) and (b) Carbon dioxide contents in seawater (test B).

Acknowledgments
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