Biorock

Biorock, also known as **Seacrete** or **Seament**, is a trademark name used by Biorock, Inc. to refer to the substance formed by electro-accumulation of minerals dissolved in seawater. Wolf Hilbertz developed the process and patented it in 1979.[1] The building process, popularly called accretion, is not to be confused with Biorock sewage treatment. The biorock building process grows cement-like engineering structures and marine ecosystems, often for mariculture of corals, oysters, clams, lobsters and fish in salt water. It works by passing a small electric current through electrodes in the water. The structure grows more or less without limit as long as current flows.

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History


Aragonite in tube

Artificial reefs have been built since the 1950s using materials including sunken ships, concrete blocks and discarded tires. However, most of these plans failed to provide coral habitat. Most notoriously, tires were strapped down off the shore of Fort Lauderdale and became an environmental disaster.[2] Some artificial reefs succeeded, but most remain relatively barren compared with natural reefs.

Biorock technology arose from experiments in the 1970s when Hilbertz was studying how seashells and reefs grow, by passing electric currents through salt water. In 1974, he found that as the salt water electrolyzes, calcium carbonate (aragonite) combines with magnesium, chloride and hydroxyl ions to slowly accrete around the cathode, eventually coating the electrode with a material similar in composition to magnesium oxychloride cements and as strong as concrete. Over time cathodic protection replaces the negative chloride ion (Cl-) with dissolved bicarbonate (HCO3-) to harden the coating to a hydromagnesite-aragonite mixture with gaseous oxygen evolving through the porous structure. Later experiments showed that the coatings can thicken at the rate of 5 cm per year. As long as current flows, the structure continues to grow and strengthen. It can heal itself if damaged, making it particularly useful as a replacement for concrete in hard-to-access locations. High levels of dissolved oxygen make it particularly attractive to marine organisms, particularly fin fish.

Hilbertz originally called his invention, on which he obtained several patents, underwater mineral accretion or accretion for short. Hilbertz's original plan was to use this technology to grow low-cost structures in the ocean for developing countries. He also envisioned accreting large aquadynamic OTEC ocean thermal energy conversion plants, both for generating power and for producing hydrogen, ammonia, and magnesium hydroxide.[3] This appeared to result in a building process largely independent of land-based resources.

His focus shifted to coral reefs after meeting Thomas J. Goreau in the 1980s. They formed a partnership. Goreau continued work on biorock technologies and coral reef restoration after Hilbertz' death in 2007. Because the biorock process uses such simple materials, electrode forms can be constructed in to mimic natural reefs. Since the combined hydrated magnesium oxychloride, brucite (magnesium hydroxide) - later hydromagnesite (magnesium chlorocarbonate) and aragonite (calcium carbonate) coating that forms is so similar to natural reef substrate, corals readily take to biorock reefs. Coral thrive on the electrified and oxygenated reef environment. One prominent example was in the Maldives during the 1998 warming, during which fewer than 5% of the natural reef corals survived. On biorock reefs there, 80% of corals flourished.[4]

With others, Hilbertz and Goreau made two expeditions to the Saya de Malha bank in 1997 and 2002. Using Biorock technology, they attempted to grow an artificial island around steel structures that were anchored to the sea floor.[5] As "Seacrete" the process was publicised in a 1992 book of futurology, *The Millennial Project*. Author Marshall Savage reiterated Hilbertz' earlier proposal that the conductive metal magnesium be extracted from ocean water, and that the process use electricity from ocean thermal energy conversion. In 2012, both Goreau and Robert K. Trench, writing together with Goreau, published works on how Biorock could generate building materials as well as restoring damaged ecosystems.[6]

Process

Applying a low voltage electric current (safe for swimmers and marine life) to a submerged, conductive structure causes dissolved minerals in seawater, principally calcium, magnesium and bicarbonate to precipitate and adhere to that structure. The result is a composite of brucite hydromagnesite and limestone with mechanical strength similar to concrete. Derived from seawater, this material is similar to the composition of natural coral reefs and sand beaches.

Constructing a reef

To build a biorock reef, a welded, electrically conductive frame, often made from construction grade rebar or wire mesh, is submerged and attached to the sea bottom. A low voltage direct current is applied. This initiates an electrolytic reaction that precipitates mineral crystals naturally found in seawater, mainly calcium carbonate and magnesium hydroxide, on the structure.

Within days, the structure takes on a whitish appearance as it becomes encrusted with precipitated minerals that add rigidity and strength. Electric fields, plus the shade and protection offered by the metal/limestone frame, attract colonizing marine life, including fish, crabs, clams, octopus, lobster and sea urchins.

Once the structure is in place and minerals begin to coat the surface, the next phase of reef construction begins. Divers transplant coral fragments from other reefs, attaching them to the ark's frame. Immediately, these coral pieces begin to bond to the accreted mineral substrate and because of evolved oxygen and the electrochemically facilitated accretion of dissolved ions, such as bicarbonate - start to grow—typically three to five times faster than normal. Soon the reef takes on the appearance and utility of a natural reef ecosystem rather than a man-made one.

A newly constructed Biorock reef set up by Gili Eco Trust in Indonesia.

Technical specifications

Biorock samples range in compressive strength from 3720 to 5350 lbf/in² (26 to 37MPa) – for comparison, the concrete typically used in sidewalks has a strength of about 3500 lbf/in² (24 MPa).

Main components of biorock include magnesium hydroxide and calcium carbonate. This composition is chiefly the result of the ionic composition of seawater.[3] One kilowatt hour of electricity accretes about 0.4 to 1.5 kg (0.9 to 3.3 lb) of biorock, depending on parameters such as depth, electric current, salinity and water temperature.[7][8]

In one study, *Porites* development was compared between colonies with and without an electric field for 6 months. The electric field was eliminated after the sixth month. Longitudinal growth was relatively high in the presence of the field, but dropped thereafter. Growth differences were significant only during the first 4 months. Girth growth differences were significant in the early months. The treatment corals survived at a higher rate.[9]

Benefits

Biorock accelerates growth on coral reefs by as much as fivefold and restoration of physical damage by as much as 20 times.[10][11] The rate of growth can be varied by altering the amount of current flowing into the structure. Biorock can enable coral growth and regrowth even in the presence of environmental stress such as rising ocean temperatures, diseases, and nutrient, sediment, and other types of pollution. When mixed with construction aggregates, it can build components on the sea floor or on land. Biorock represents the only known method that can sustain and grow natural coral species using only basic conducting elements, typically of a common metal such as steel.

Electrolysis of biorock reefs enhances coral growth, reproduction and ability to resist environmental stress. Coral species typically found on healthy reefs gain a major advantage over the weedy organisms that often overgrow them on stressed reefs.

Biorock reefs grow rapidly and strengthen as they age. They thus have great potential for many applications, such as making breakwaters. If waves or colliding ships cause damage, renewed accretion makes them, to an extent, self-repairing.

Biorock is cost-effective, requiring only metal bars or equivalent and electricity. While electricity provided from fossil fuels generates CO_2, biorock projects often use renewable solar power, wind power, tidal power, or wave power. The resulting material is cheaper than concrete blocks in many places, depending on electricity and cement transport costs.[12]

Biorock structures can be built in any size or shape depending only on the physical makeup of the sea bottom, wave, current energies and construction materials. They are well suited for remote, third world sites where exotic building materials, construction equipment and appropriately skilled labor are not available.

Potential to grow back eroded beaches

Biorock structures are extremely effective at preventing beach erosion and restoring already eroded beaches. Shorelines are highly susceptible to beach recession and loss due to climate change bringing about rising sea levels and increasingly frequent and powerful storms. Conventional methods of combatting this employ large structures such as breakwaters that are designed to reflect waves, thus preventing erosion. However, this method is problematic and actually contributes to beach erosion. As each wave crashes, the force it exerts on the structure is doubled due to the reversal of the wave direction vector. This reflected wave then carries the sand at the structure's base back out to sea. This repeats until the structure is dug out and falls, or breaks.[13] Natural reefs prevent erosion by dissipating around 97% of wave energy, and grow beaches by depositing skeletons of dead coral and algae.[14][15] Biorock Anti-Wave (BAW) structures mimic these natural reefs, reaping their benefits and solving some of the challenges they have in storm dissipation. BAW structures can be built in the shape of an upside-down wave to provide optimal wave dissipation. Additionally, the self-healing quality of Biorock ensures structures will survive even the most devastating storms.[14]

BAW structures in Turks and Caicos survived the two worst hurricanes in the history of the islands, which occurred three days apart and damaged or destroyed 80% of the buildings on the island. Sand was observed to build up around the bases of Biorock reef structures.[14]

In Maldives in 1997, BAW structures helped save several buildings, including a hotel, that had risked washing away due to severe beach erosion. A 50 meter long BAW structure was built which stabilized and ultimately reversed erosion in several years, even allowing the beach to survive a tsunami in 2004

Drawbacks

While Biorock structures produce wonderful results, they require constant power to maintain them. In Maldives, several Biorock reefs successfully survived a 1998 bleaching event that killed off nearly all wild coral, but were then taken off power. They survived until 2016 when another bleaching event killed them all.[14]

The electric field that Biorock produces is so far known to be safe to wildlife, however this doesn't mean that it doesn't affect wildlife. A study conducted in the Bahamas in 2015 showed that the electric field deterred sharks, specifically the bull shark and the Caribbean reef shark, from swimming and feeding in the area. The electric field is believed to affect sharks because of their electroreception abilities, however species with similar capabilities such as the bar jack and Bermuda chub did not appear to be affected by the electric field.[16]

Distribution

As of 2011, biorock coral reef projects had been installed in over 20 countries, in the Caribbean, Indian Ocean, Pacific and Southeast Asia. One project is located on one of the most remote and unexplored reef areas of the world, the Saya de Malha Bank in the Indian Ocean.[17] Other biorock projects are located in French Polynesia, Indonesia, Maldives, Mexico, Panama, Papua New Guinea, Seychelles, the Philippines and Thailand. Indonesia has the most biorock projects, with sites near over half a dozen islands, including the world's two largest reef restoration projects: Pemuteran with the Karang Lestari and the Gili islands with the Gili Eco Trust.[18] Non-coral biorock projects have been conducted in places such as Barataria Bay, Galveston, seagrasses in the Mediterranean, oyster reefs and salt marshes in New York City, in Port Aransas, and in St. Croix.

Maldives

On Vabbinfaru island in the Maldives, a 12-meter, 2 ton steel cage called the Lotus was secured on the sea floor. As of 2012, coral was so abundant on the structure that the cage is difficult to discern. The 1998 El Nino killed 98% of the reef around Vabbinfaru. Abdul Azeez, who led the Vabbinfaru project, said coral growth on the structure is up to five times that of elsewhere. A smaller prototype device was in place during the 1998 warming event and more than 80% of its corals survived, compared to just 2% elsewhere.[19] However, power is no longer supplied to the project, leaving it vulnerable to the next round of bleaching.

Biorock Technology Links

Global Coral Reef Alliance
https://www.globalcoral.org/

Beach Restoration
https://www.youtube.com/watch?v=Mxi1SvmzwcA

Reef Growth
https://www.youtube.com/watch?v=Rx8TV9Kd0ns