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Basic Technology: Mineral Accretion for Shelter. Seawater as Source for Building.

Two resources not yet fully utilised for the production of building materials are: volcanoes and oceans.

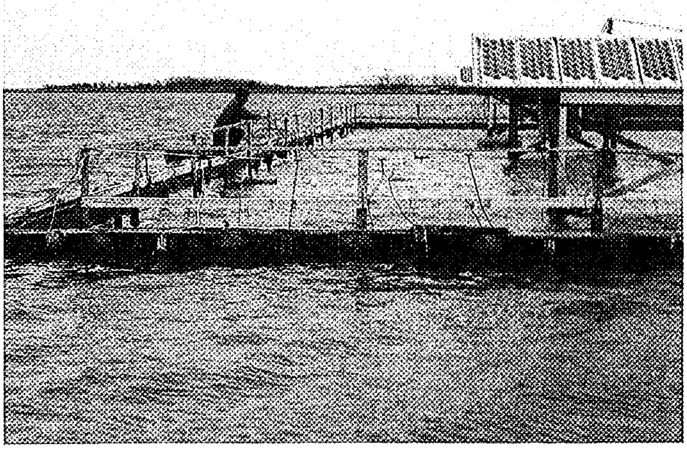
In an article in MIMAR 31 the use of sulphur resulting from volcanic activity was explained. The potential of mineral accretion of seawater is proposed in the following pages. This resource for low-cost materials is one exciting possibility for providing better human shelter.

Oceanography

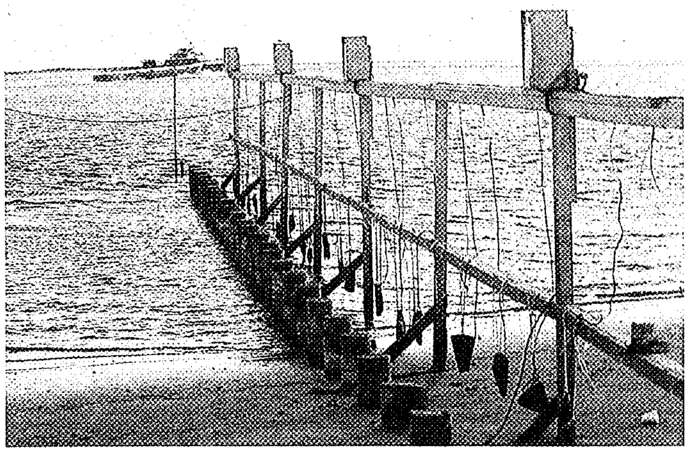
The understanding of the oceans is of basic interest for mankind. They are sources for food, chemicals, drinking water, oil and gas as well as being important for communication and transportation. In addition, nearly unlimited mineral resources in solution are available by extraction from seawater. The volume of the oceans is so large and the mixing so complete that no appreciable change takes place within periods less than one thousand years. The study of oceanography consists, in fact, of several sciences: physical, chemical, biological and geological. In recent years a new science dealing with the practical uses of ocean resources, applied oceanography, has been added.

As architects, interested in improving the housing conditions of the world's population, it is important to encourage the scientific community to find ways for taking care of the expanding social needs of its population. Priority should be given to changing from what was largely scientific study of the sea to a more effective use of this natural resource for solving a basic problem, that of human shelter. We must transfer scientific discoveries into practical uses. Architects have the important responsibility to reduce building costs as well as to promote uses of new natural resources. This is the case for mineral accretion of seawater.

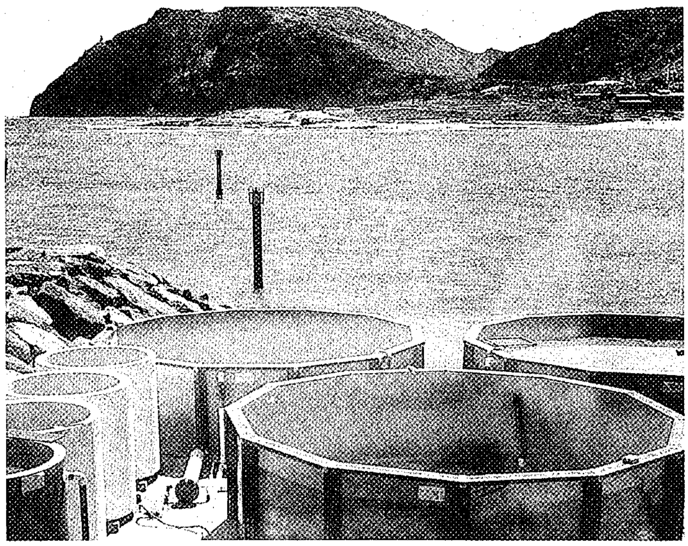
The chemical constituents of



Solar energy of various forms can be used everywhere for the electrodeposition of minerals; furthermore wind energy, so abundant on the sea coast, is an ideal source for producing building components, particularly in isolated communities. The architect Hilbertz used both sources of energy in the Gulf of Mexico.

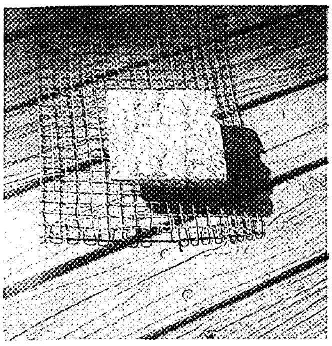


A metal mesh immersed in seawater and connected to the negatively-charged electrical current makes possible the precipitation of calcium and magnesium salts. Although the total amount of dissolved salts is variable, the relative proportions of major elements, such as sodium, chlorine, magnesium, and calcium are constant across the five oceans. Note in this photograph the positive terminals (anodes) manufactured with carbon or graphite material; they are located in the vicinity of the cathodes for producing galvanic cell in this way.



A view of concrete tanks used in aquaculture in Honolulu, Hawaii. Similar installations could be used in mineral accretion of seawater.

Text and photographs by Alvaro Ortega.



View of the metal mesh used as a negative terminal for the precipitation of positively-charged calcium carbonates and magnesium hydroxides.

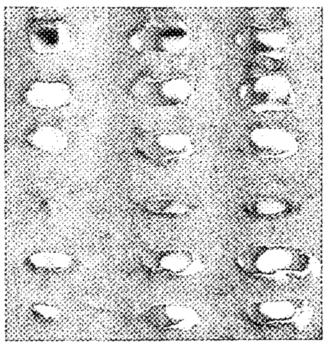
seawater have been studied since the 1870's. The first international organisation interested in oceanography was created in Copenhagen,, Denmark, in 1902. The Oceanographic Institute in Paris was founded in 1911, and the one in the USSR was created in 1945 in Moscow. In Washington, USA, The National Oceanic and Atmospheric Administration was organised in 1970, while UNESCO created in 1973 the Oceanographic Committee, responsible for the coordination of the international scientific community interested in ocean resources.

History

The electrolysis of water was discovered in the early 19th century by the English physicist and chemist Michael Faraday, whose many experiments contributed greatly to the understanding of electromagnetism and provided the basic laws of electrolysis. The decomposition of chemical compounds by an electric current is a phenomenon called electrolysis.

It was only in 1936 that G.C. Cox requested a US patent for protecting metallic surfaces using electrolysis of seawater. Magnesium and calcium salts were used for the first time in practical innovation, the protection of metals in seawater.

The German-born architect Wolf H. Hilbertz experimented in the early 1970's with growing architecture in the ocean using the electrodeposition of seawater. Hilbertz obtained his first patent (US No. 4.246.075 – Jan 1981) related to "Mineral Accretion of Large Surface Structures, Building Components and Elements"; since then Hilbertz has been promoting the use of electrolysis in seawater for the protection of timber pilings and for repairing reinforced concrete structures by mineral accretion. The two patents are: "Accretion Coating and Mineralisation of Materials for Protection Against Biodegradation" (US – No. 4.461.684 – July 1984), and "Repair of Reinforced Concrete Structures by Mineral Accretion" (US No. 4.440.605 – April 1984).



The mineral accretion process operates only during the period when the electrical current is applied. When the thickness of the required element is obtained, the electricity is disconnected and the hardening of the material takes place in seawater. This process, called biophasing, may require a few months. Production of screens, can be achieved as shown in this photograph once the mechanism is understood. In most cases visible accretion requires only 24 hours, thicker layers need days and sometimes even weeks for thick accretions.

Availability of Resources

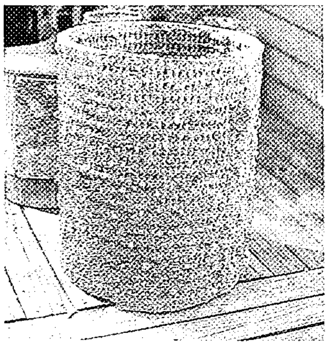
The oceans are basins in the earth containing saltwater. More than 70 per cent of the earth's surface is covered by ocean, with an average depth of 4000 metres. They hold in solution vast mineral resources which, if used properly, could solve the present lack of adequate human shelter. Seawater contains the majority of known chemical elements, the most abundant components of which are: sodium, magnesium, calcium, potassium and chlorine. An important feature of seawater is that ratios of the more abundant components remain almost constant as oceans have become well mixed.

The electrodeposition of minerals is possible when they are suspended in water. Water is one of the most important of all substances, as well as being one of the most widely distributed; it is the universal solvent, being the most effective of all liquids known to men. Almost all chemical reactions require water as a medium. The amount of dissolved mineral is defined as its salinity and means the grammes contained in one kilogram of seawater. The average salinity of the ocean water is about 35 grammes per kilogramme or 35 parts per one thousand. The salt content of the ocean ranges from 3.2 per cent to 3.6. Seas receiving extensive river water may have lower values. Evaporation and freezing are two other factors that increase the salinity of seawater.

The major constituents of seawater are (in grammes per kilogramme of water):

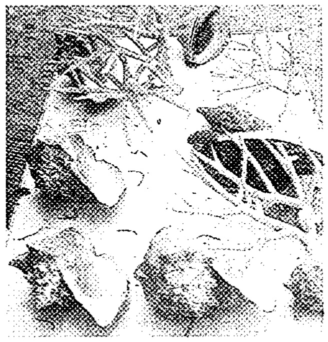
Chloride (Cl)	19.0
Sodium (Na)	10.5
Sulphate (So^4)	2.6
Magnesium (Mg)	1.3
Calcium (Ca)	0.4
Potassium (K)	0.4
Total salinity	34.2

The salt content of the open ocean rarely exceeds 37 parts per thousand and not less than



Water storage tanks for aquaculture facilities could be produced as shown in this photograph.

33 parts per thousand; however, in smaller bodies of water like the Red Sea and the Arabian Sea the salinity increases up to 40 parts per thousand. The Black Sea has only 20 parts per thousand due to the large amount of river water it receives. Seas with low salinity require longer periods of accretion time but it is still



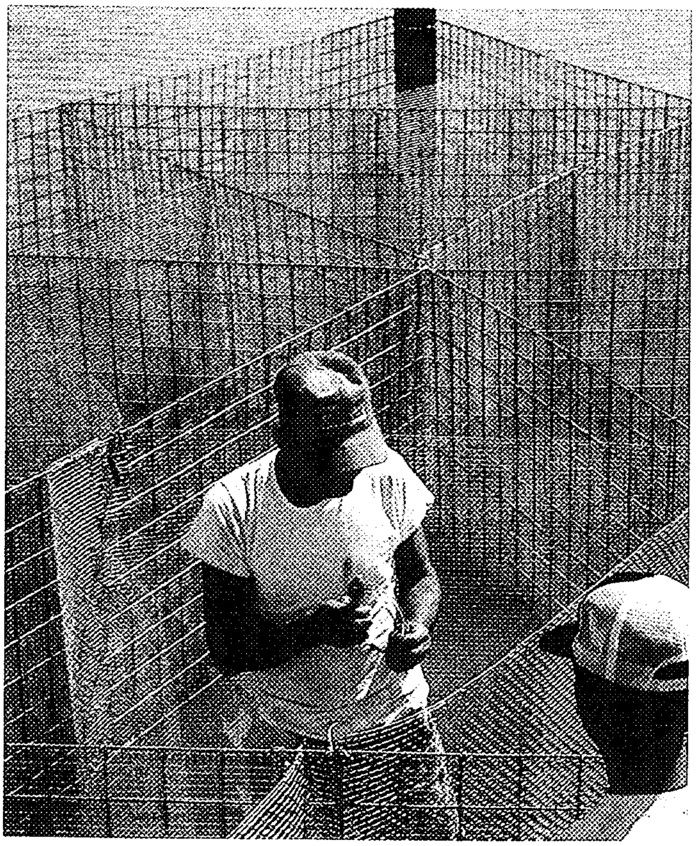
View of sea shells composed of calcium carbonates enclosed in an organic matrix. In addition the mineral composition of human blood is similar to the composition of seawater.

feasible to obtain materials by electrolysis from the salt water.

Blood serum used in medicine has a similar chemical composition to that of seawater. Both contain calcium carbonate ($CaCo^3$) and magnesium hydroxide ($Mg(OH)^2$). When these two chemcial elements are extracted they form bone, tooth or shell material, with a strength similar to that of stone or even concrete. Seawater can be an important source of chemical building materials in nature. The process of extracting them is called electrodeposition. Marine organisms synthesize shell materials from seawater utilising their negative electrical charge that attracts the positively charged materials.

Principles of Electrolysis

Mineral accretion is produced when an electrically-conductive material, such as metal mesh, is connected to the negative pole (cathode) of a direct current supply and placed in seawater. The positive terminal (anode) is located in its vicinity, thereby producing a galvanic cell. This inert electrode is manufactured



Another important use of mineral accretion is in forming artificial reefs as a tool for increasing fish populations. Wire mesh of different gauges is particularly well-suited to this end. This is a view of a demonstration artificial reef constructed by Hilbertz in St. Croix in 1976.

A view of curved walls which are a practical way for increasing the strength of a 8mm thick plate. These experiments were carried out in Argentina, and this concept could be used in mineral accretion, gaining stability by curving the panels.

using carbon or graphite material.

The positively-charged calcium carbonate and magnesium hydroxide, which are dissolved in seawater are accreted around the negatively-charged metal. The metal mesh is pre-shaped in such a way as to take structural advantage of its new form. It therefore has three functions: 1) to attract minerals by electrolysis; 2) to give a structural shape to the building component, and 3) to act as reinforcement for the sea-concrete.

The fact that calcium carbonate is an abundant material and widely distributed in nature (as is also the case of magnesium hydroxide) makes its use highly attractive for pursuing an unprecedented effort to solve the problem of human shelter.

Magnesium hydroxide is the eighth most abundant element in the earth crust, and is the third highest in concentration in seawater.

Energy Required

The electrical power required is about two kilowatt hour per kilogramme of accreted seawater concrete. The electricity used ranges from 2 to 16 volts and from 30 milli-amperes to 3 amperes per square metre area of cathodic material. Voltage is kept to a minimum in order to optimise the electrical power input. Higher strength components are produced using lower current densities, but requiring additional accretion time. Building components no longer connected with electricity are left to cure in seawater by interaction with marine organisms.

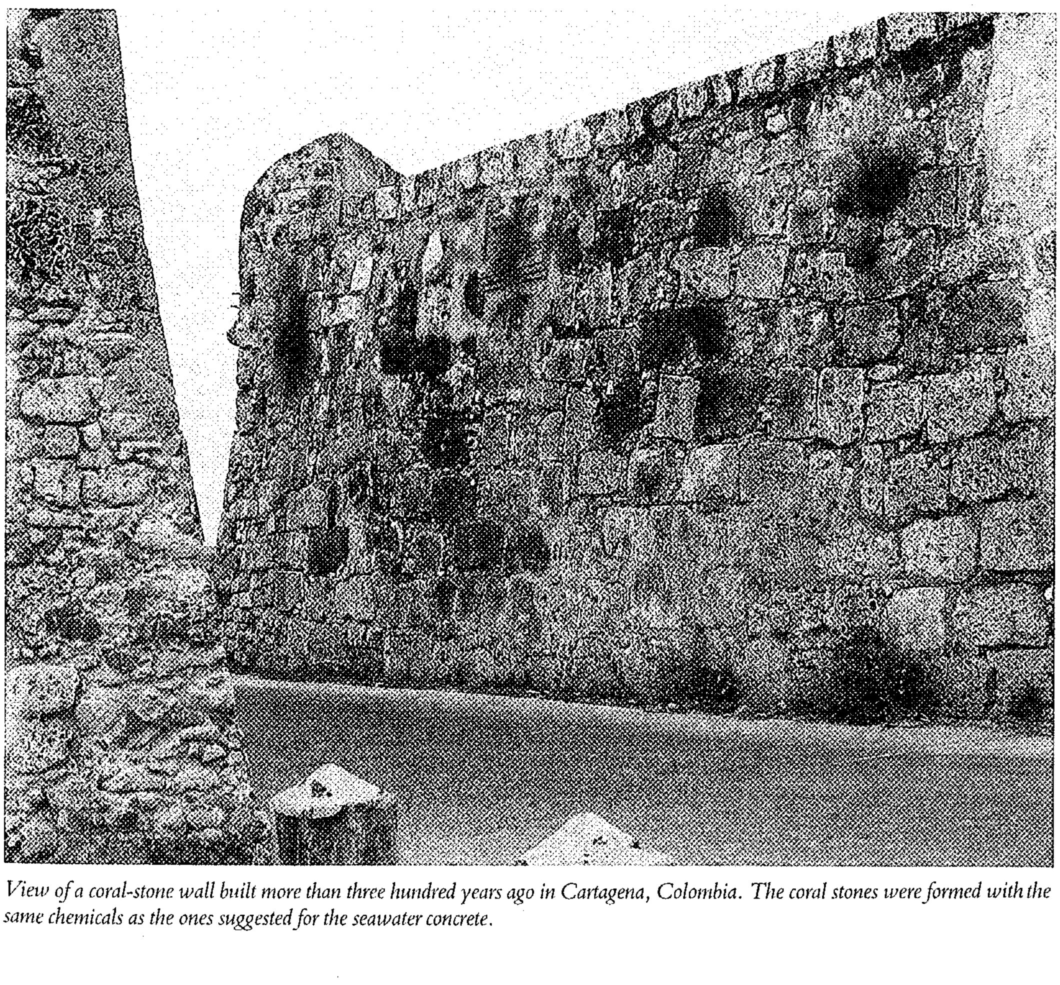
Conclusion

Electrochemical accretion of dissolved minerals in seawater is a technology having great potential for solving a basic human need, that of shelter; with the vast mineral resources of the ocean it can be done. Mineral deposition and calcification is possible when these are suspended in water. The electrolytic process used in mineral accretion can be artificially stimulated. Thus, the potential of mineral accretion technology for structural applications is unlimited.

Accretion technique is very simple and could encourage self-help housing construction activities along many of the coastal areas of under-paid countries. Energy requirements are reasonable (2 Kw/hr per 1 Kg of material).

We need additional resources for the production of building components. During the last hundred years man has been using natural resources, which have taken millions of years to accumulate and are now rapidly being depleted by overuse. Building with renewable resources, such as timber and organic fibers has also been mismanaged. On most continents we have been cutting trees faster than they grow. Therefore, the large amount of minerals dissolved in the ocean are one of the last resources available to mankind for solving the need for building material economically. Electrolysis is used in industrial processes for refining metals: copper, aluminium, zinc and magnesium. It can also be used in mineral accretion of seawater for producing a seawater concrete with similar strength to that of Portland-cement concrete.

Examples of research on fiber-cement roofs and walls undertaken for the United Nations Centre for Human Settlements by the author of this article. The basic concepts are still relevant for use with the results of mineral accretion of seawater, in order to obtain strength by shaping the building components. Generally the cost of roofing represents up to 30 per cent of the entire expense of basic low-cost house. Therefore, research towards reducing roofing costs is highly important.



View of a coral-stone wall built more than three hundred years ago in Cartagena, Colombia. The coral stones were formed with the same chemicals as the ones suggested for the seawater concrete.

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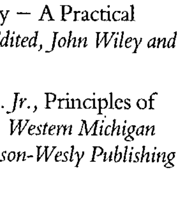

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