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COMBINATION TECHNOLOGY OF GEOTEXTILE TUBE AND ARTIFICIAL BEACHROCK FOR COASTAL PROTECTION

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ABSTRACT: In recent years, traditional forms of river and coastal structures have become very expensive to build and maintain, because of the shortage of natural rock. Therefore, the materials used in hydraulic and coastal structures are changing from traditional rubble and concrete systems to cheaper, sustainable, and eco-friendly materials and systems such as artificial rock, gabion, slags, geosynthetics, and so on. Moreover, shorelines are being continually eroded by the wave action of the sea, and the river and coastal structures are frequently damaged by both anthropogenic and natural causes such as over wash and storm. How to deal with eroding coastal problems is a main topic of this article. Recently, artificial beachrock and geotextile tube technology has changed from being an alternative construction technique and, in fact, has advanced to become the prime solution of choice. Therefore, the objectives of the present study is to find out the feasibility to protect coastal erosion in Asia along with using artificial beachrock and geotextile tube technology in a cheaper, sustainable and eco-friendly way.

Keywords: Artificial beach rock, Geotextile tube technology, Coastal erosion, Sand cementation, Sustainable, Eco-friendly

1. INTRODUCTION

The problem of coastal erosion is nothing new, but in recent years, it seems to have increased in speed especially in Asia. Because in Asia there are a lot of islands, long coastal lines and population density is much. Therefore, initially we have focused on Asia and in future we will work on other part of the world regarding coastal erosion. Coastal erosion has long been a significant problem globally, typically due to anthropogenic changes along the coastline, and it poses a hazard for people residing in these areas. Erosion of the sandy shore is often used to refer to changes in the coastline due to the collapse of the sediment balance. To prevent, or at least minimize damage from erosion, a combination of various structures and processes has been traditionally used, including embankments, revetments, jetties, artificial reefs, offshore breakwaters, and sand bypassing [5].

The costs of installing hard structures for coastal protection are very high and development within coastal areas has increased interest in erosion problems; it has led to major efforts to manage coastal erosion problems and to restore coastal capacity to accommodate short-and long-term changes induced by human activities, extreme events and sea level rise. The erosion problem becomes worse whenever the countermeasures (i.e. hard or soft structural options) applied are inappropriate, improperly designed, built, or maintained and if the effects on adjacent shores are not carefully evaluated.

Therefore, increased interest in soft structures for coastal protection and a combination of hard and soft structures like geotextile tube technology is predominating and is consonant with advanced knowledge on coastal processes and natural protective functions and researcher showed that, artificial beachrocks (manufacture artificially in the natural condition) have the potential to inhibit coastal erosion [5]. Recently, geotextile tube technology has changed from being an alternative construction technique and, in fact, has advanced to become the prime solution of choice. Geotextile tubes, hydraulically or mechanically filled with dredged materials (woven, non-woven, and composite synthetic fabrics), have been variously applied in hydraulic and coastal engineering fields. The geotextile tube technology is mainly used for flood and water control, but they are also used to prevent beach erosion as well. In additionally, considering the use of artificial rock to preserve such submerged-looking islands above sea level, Danjo and Kawasaki [6], [8] conducted several studies in Okinawa and Ishikawa, Japan. They found sufficient information to build artificial beachrock. Considering this importance such type of study is also essential in Asia, as and other vulnerable country to climate change, to inhibit the coastal erosion due to sea level rise using artificial beachrock.

Therefore, the objectives of the present study is to find out the feasible method to protect coastal erosion in Asia along with using artificial beachrock (Microbially Induced Carbonate Precipitation-MICP method) and geotextile tube technology in a cheaper, sustainable and eco-friendly way.

2. METHODS

Data used in this study is obtained from literature survey of related works. Data were organized by geographical location of beachrocks and coastal erosion in Asia. Quantitative scenario of coastal erosion and protective measures in Asia was shown in the obtained data.

For the prevention of coastal erosion quantitative information for the prospects of artificial beachrocks formation, their cement components, geotextile tube technology, their prospects, formation and composition etc. were collected, compiled and compared. Since this was the information that we deemed would be essential for the manufacturing of artificial beach rock and at the same time possible protective ways for the control of coastal erosion.

3. RESULTS AND DISCUSSION

3.1 Coastal Erosion in Asia

Coastal erosion has been studied in Viet Nam [3]; Bangladesh [4], [14], [17]; Malaysia [22]; Indonesia [33]; Sri Lanka [25]; India [12], [18]; China [2], Thailand [29] and Japan [6], [8], [16], [19] which is indicated in the Fig. 1.

From the Fig. 1, it is seen that over 90 % of beachrocks are distributed between the proximity of 40´N and the Tropic of Capricorn. The geographic distribution of beachrocks was not concentrated near the equator. In particular, high concentrations of beachrocks were found at relatively high latitudes areas. This precludes the notion that beachrocks are concentrated only in areas where the temperature of the air or sea is high [6]. Coastal erosion and accretion are natural processes; however, they have become anomalous and widespread in the coastal zone of Asia and other countries in the Indian ocean owing to combinations of various natural forces, population growth and unmanaged economic development along the coast, within river catchments and offshore. This type of erosion has been reported in China, Malaysia, SriLanka, India, Japan, Indonesia, Viet Nam, Thailand, and Bangladesh.

Bilan [2] reported that the erosion rate in the northern part of Jiangsu Province in China is serious and as high as 85 metres/year; in Hangzhou Bay the rate is 40 metres/year, while in Tianjin it is 16-56 metres/year. Erosion persists even where preventive measures such as sea dykes are constructed. Beach scour has been found along coasts with sea-dyke protection. This erosion is attributable to many factors such as river damming and diversion, that leads to less sediment supply to the coast, and the clearing of mangrove forests, which makes coastal areas more susceptible to the hazard.

According to Othman [22] nearly 30 percent of the Malaysian coastline is undergoing erosion.

In Vietnam, most of the coastline in the south that is sited in a wide and flat alluvial fan and bordered by tidal rivers fringed by wide mangrove swamps, has been eroded continuously at a rate of approximately 50 metres/year since the early twentieth century. Erosion still occurs in the central coastal zone of Viet Nam and preventive measures such as sea dykes, revetments, and tree plantations have been implemented to prevent further erosion [3].

Sri Lanka’s experience with coastal erosion dates to 1920 and approximately US$30 million has already been spent on breakwaters and other construction to combat coastal erosion on southern and western coasts however, coastal erosion persists in some coastal areas [28].

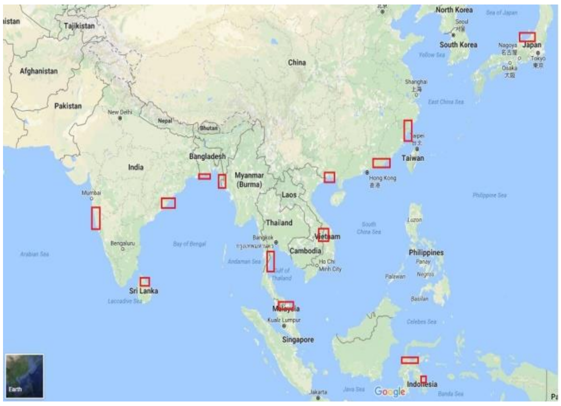

Fig. 1 Location of beachrock deposition in some Asian countries (google.map)

In India, the rapid erosion of the coast of Sagar Island in West Bengal, India, is caused by several processes that act in concert; these are natural processes that occur frequently (cyclones, waves and tides that can reach six metres in height) and anthropogenic activities. The erosion rate from 1996 to 1999 was calculated to be 5.47 square kilometres/year [12]. The areas that are severely affected by erosion are the north-eastern, south-western and south-eastern faces of the island. Malini and Rao [18] reported coastal erosion and habitat loss along the Godavari Delta front owing to the combination of the dam construction across the Godavari and its tributaries that diminishes sediment supply to the coast and continued coastal land subsidence.

In Indonesia, coastal erosion started on the northern coast of Java Island in the 1970s when most of the mangrove forest had been converted to shrimp ponds and other aquaculture activities, and the area was also subjected to unmanaged coastal development, diversion of upland freshwater and river damming. Coastal erosion is prevalent throughout many provinces [33] such as Lampung, Northeast Sumatra, Kalimantan, West Sumatra (Padang), Nusa Tenggara, Papua, South Sulawesi and Bali.

In Thailand, intensification of coastal erosion came to notice during the past decade overall, the net erosion is approximately 1.3 to 1.7 metres/year along the southern Thailand coastline. Total area losses amount to 0.91 square kilometres/year for the Gulf coast and 0.25 square kilometres/year for the western coast [29].

Khan [17] and Islam [14] studied coastal erosion and accretion activities in Bangladesh. Heavy discharge currents through the GBM (Ganges-Brahmaputra-Meghna) river system, wave action due to strong southwest monsoon winds, high astronomical tides as well as sea level rise (SLR), and storm surges in the Bay of Bengal are the main causes of erosion in the coastal area of Bangladesh [14]. Erosion due to SLR has been discussed by Islam [14] in his study which was done under the U.S. Country Studies Program, and some of the salient features of the study are presented here.

The study was based on the erosion formula given by Bruun [34].

$$x=ab/(e+d) \tag{1}$$

Where x is the shoreline recession due to SLR, a is the rise in water level due to SLR, e is the elevation of the shore, and d is the depth of water at a distance b from the coastline. Islam [14] applied the formula to the eastern region, where the longest continuous sandy beach situated, of Bangladesh.

3.2 Coastal Protection

Natural beachrocks, which are formed naturally on beaches, have attracted attention as a model for artificial rocks. Danjo and Kawasaki [5] proposed a new method to protect coastlines from erosion, the use of artificial rock that auto-repairs by means of sunlight, seawater, and bacteria. Their model of artificial rock is beachrock. Beachrock is a type of sedimentary deposit that generally occurs on tropical and subtropical beaches since intertidal lithification of loose beach sands and gravels by carbonate cementation.

Beach rock is generally limited to tropical and subtropical climates, though not every tropical beach has beach rock Beach rock has also been reported from temperate regions, but such occurrences are rare. Around the world, beachrocks have been reported to form over several thousand years [31] owing to interactions among sand supply, cement precipitation from seawater and coastal erosion by ocean waves [5]. Therefore, it may be possible to slow down the erosion of coasts by making man-made beachrock from coastal sands. Because this artificial rock is made of local materials, it has the potentiality to be a cheaper and eco-friendly product [5].

3.3 Characteristics of Beachrock

Most recent beachrock is formed on beaches in the same regions that favour coral reef formation. This is generally below 25° latitude where there is a well-defined dry season and “the temperature of ground water at a depth of about 76 cm in beaches remains above 21°C for at least 8 months of the year” [24]. Several theories have been proposed to explain beachrock formation, which can be divided into physico-chemically and biologically induced precipitation of calcium carbonate. Most of the theories have been formulated to explain occurrences of beachrock.

Physico-chemical models explain marine carbonate cement precipitation by the soaking of beaches during high tides and evaporation of sea water during low tides [11], enhanced by (daytime) solar warming of the beach.

Biological processes may have an important role in beachrock formation. Biological activity controls the partial pressure of CO_2 by its consumption, thus promoting the precipitation of $CaCO_3$ [13]. Ammonification of amino-acids, sulphate reduction and other bacterial processes taking place during organic matter degradation promote carbonate precipitation by raising the pH, furthermore, organic matter may promote carbonate precipitation [32].

Accordingly, there are several theories regarding the process of beach sand cementation. Different mechanisms of cementation appear to be responsible at different localities. The primary mechanisms proposed for the origin of beachrock cements are as follows:

1) Physicochemical precipitation of high-Mg calcite and aragonite from seawater because of high temperatures, $CaCO_3$ super saturation, and/or evaporation [10],

2) Physicochemical precipitation of low-Mg calcite and aragonite by mixing of meteoric and fresh ground water with seawater [26],

3) Physicochemical precipitation of high-Mg calcite and aragonite by degassing of CO_2 from beach sediment pore water [30], and

4) Precipitation of micritic calcium carbonate as a by-product of microbiological activity [21].

3.4 Properties of Beachrock and Beach Sand in Asia

From the Fig. 2 and Table 1, it is shown that, the main component for the formation of beachrock is CaO and SiO_2. But other components like Al_2O_3, TiO_2, and FeO also play a vital role for the beachrock formation.

Table 1: The main component for the formation of beachrock in some Asian countries

Location	Rock Formation Type	Component Materials	References
Bangladesh	Calcareous coral sand, broken coral or limestone	Kaolinite	[17]
India	Calcareous coral sand, limestone	Quartz, Feldspar, Kaolinte	[23]
Sri Lanka		Quartz, Calcite, Dolomite, Aragonite	[15]
Vietnam	Data is not available		
Malaysia	Calcareous, Aragonite		[1]
Indonesia	Data is not available		
China	Calcareous sand, Lime stone		[15]
Thailand	Data is not available		
Japan	Shell sand, foraminifer, sand, gravel	Aragonite, Mg calcite	[5]

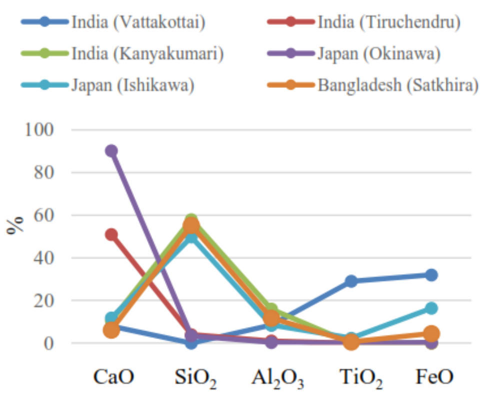

Fig. 2 Beachrock compositions in some Asian countries [17]

3.5 Artificial Beachrock Formation through Beach and Sand Solidification

Danjo and Kawasaki [5]-[7] conducted several studies in Okinawa and Ishikawa, Japan. They found sufficient information to build manmade beachrock. Danjo and Kawasaki [5] perform coral sand solidification test using ureolytic bacteria (*Pararhodobacter* sp.) and found this type of bacteria can solidify coral sand precipitating $CaCO_3$. Considering this importance such type of study is also essential in Asia, and other most vulnerable country to climate change, to inhibit the coastal erosion due to sea level rise.

Danjo and Kawasaki [5]-[7] found that, Column specimens were cemented up to UCS of 10 MPa after 28 days under the conditions (curing temperature; 30°C, injection interval; 1 day, Ca^{2+} concentrations in cementation solution; 0.3 M). Based on formation methods observed by Danjo and Kawasaki [5]-[7] the sand cementation process is very much suitable, eco-friendly, cheaper and sustainable for the areas in Asia where the temperature, sand properties and other conditions is almost same as Japan and the results of this study will contribute to the application of a new technique for coastal sand improvement and bio-stimulation.

3.6 Protective Coastal Protection Learned from Beachrock Formation: Through Geo-textile Tube Technology

The recent trend in the mitigation of coastal erosion and costal protection has been shifted now-a-days towards soft novel cheaper, sustainable and eco-friendly methods. Pro-active methods and solutions are being developed and employed, which are not only eco-friendly, construction-friendly and cheaper but also address the root cause of the problem without much adverse effects. Such kind of modern tool is geotextile tube which is one of the geosynthetics structures that are increasingly used in coastal protection. They are made from polypropylene (PP), polyester (PET), polyethylene (PE), polyamide (nylon), olyvinylidene chloride (PVC), and fibreglass. Sewing thread for geotextiles is made from Kevlar or any of the above polymers [20]. Different fabric composition and construction are suitable for different applications.

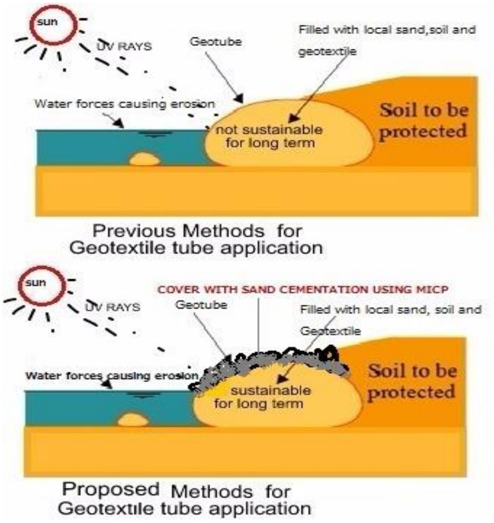

Fig. 3 Proposed Coastal Protection Method

Traditional Geotextile tubes widely used for dewatering, flood control, and coastal protection. Geotextiles are either woven or non-woven permeable fabric or synthetic material which can be used in combination with geotechnical engineering material [27]. But our proposed method is coastal protection along with MICP method and these "Geotube" (Fig. 3). In case of traditional methods, different rays from sun can damage the "Geotube" after a certain time and soil protection may not be sustainable and the cost of re-constructing "Geotube" is much. But, in our proposed method, sand cementation using MICP method can be applied over the "Geotube". As a result, the surface of the coast and "Geotube" will be strengthened and will remain loner and soil will be protected. In this method, the cost is low comparatively and local ureolytic bacteria is used, so this is eco-friendly and sustainable. This method can be applied in a broad range of civil engineering applications including construction, paving, drainage and other applications.

4. CONCLUSIONS

Finally, we can say that, the deposition of beach rock using MICP method is of significance because of the timing of diagenesis and the mode of cementation. Recently, geotextile tube technology has changed from being an alternative construction technique and, in fact, has advanced to become the prime solution of choice. But the method is not sustainable and time consuming and sometimes costly. However, the lower resistance of geotextile to damage needs to be overcome to ensure the longer service period of the geotextile tubes. Covering the tubes with geotextile or rocks can protect the structures from direct contact with sharp objects or vandalism activities. So, for the protection of coastal erosion geotextile tube technology along with MICP method can be applied which is very much eco-friendly, cheaper, and sustainable. Although, sand cementation and geotextile tube technology procedure is poorly understood till now. However, actual field trials are always recommended prior to final application.

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