# Elemental and Mineralogical Analysis of Beachrock in Uswetakeiyawa, Sri Lanka with a Focus on Developing a Sustainable Ground Improvement Method

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**Abstract**

The concept of using biological process in soil improvement which is known as bio-mediated soil improvement technique has shown greater potential in engineering applications in terms of performance and environmental sustainability. In this research we performed field investigations and laboratory tests to understand the major composition of beachrocks in Uswetakeiyawa, Sri Lanka with a focus on developing a sustainable bio-mediated ground improvement Method. We performed elemental and mineralogical analyses of the beachrocks and seawater in the Uswetakeiyawa beachrock sites. Our focus was on the cement formation mechanism of beachrock. Uswetakeiyawa beachrock composition was mainly analyzed by using Energy Dispersive X-ray spectroscopy (EDX) and scanning electron microscope and its formative environment (Beach sand and sea water) was analyzed using standard sieve analysis, EDTA titrametry, Atomic Absorption Spectroscopy(AAS) and Iron Chromatography. Overall values suggest that the studied Uswetakeiyawa beachrock formation is consisted with CaO and MgO. The observations suggest that beachrock show similarities with Indian and Japanese similar occurrences. The beachrock cement is similar to Aragnite that observed in the majority of the sites globally.

**Keywords:** Energy Dispersive X-ray spectroscopy, EDTA titrametry

## 1. Introduction

Ground improvement means a technique that uses to improve the engineering properties of the soil mass. With growing concern regarding the sustainable development, environmentally friendly methods for ground improvement are needed. Biogrouting is one such emerging methods, in which microorganisms are used to induce carbonate precipitation in the subsurface in order to increase the strength and stiffness of granular soils[1]. Hence we are going to consider the use of man-made rocks in biological means. Our model of artificial rock is beachrock in Sri Lanka.

In this research we performed field investigations and laboratory tests to understand the major composition of beachrocks and in Uswetakeiyawa, Sri Lanka and its formative environment with a focus on developing a sustainable ground improvement Method. We performed elemental and mineralogical analyses of the beachrocks and seawater in Uswetakeiyawa beachrock sites. Uswetakeiyawa beachrock was mainly analyzed by using Energy Dispersive X-ray spectroscopy (EDX) and its formative environment (sea water) was analyzed using titrametry, Atomic Absorption Spectroscopy (AAS) and Iron Chromatography.

## 2. Study Area and Sample Locations

Uswetakeiyawa beachrock site is located approximately 14.5 km North from Colombo.

This area is considered to be rich with beach sand and Holocene beach ridges and dunes. At this locality the samples were collected from 12 points along the tide line i.e. along the horizontal transect. In each location around 2 kg bulk of beach rock samples were collected (Fig.1 and Table 1).

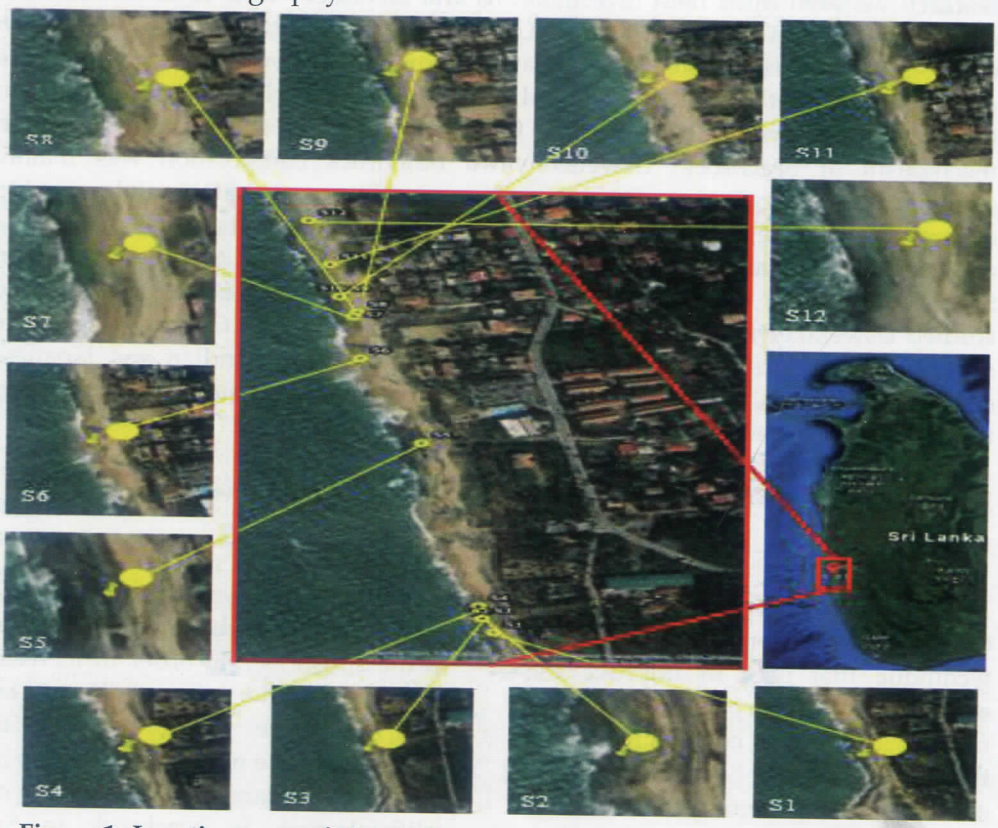


**Figure 1- Location map of Uswetakeyyawa, Sri Lanka with sample locations**

**Table 1 - The 12 sample locations selected along the shore at Uswetakeiyawa beach**

| Locaion No | GPS coordinate Latitude | Longitude |
|---|---|---|
| S 1 | 202897N | 99224E |
| S 2 | 203163N | 99180E |
| S 3 | 203353N | 99130E |
| S 4 | 203498N | 99097E |
| S 5 | 202877N | 99233E |
| S 6 | 202898N | 99225E |
| S 7 | 202917N | 99222E |
| S 8 | 203432N | 99113E |
| S 9 | 203383N | 99120E |
| S 10 | 203360N | 99133E |
| S 11 | 203290N | 99135E |
| S 12 | 207474N | 98169E |

## 3. Methods

The research consists three main parts; 1) Mineralogical Analysis of the beach rock and its formative environment, 2) Microbiological analysis of the beach rock and its formative environment and 3) Cementation analysis of the beach rock. This paper covers the Mineralogical analysis of the beachrock and its formative environment.

### 3.1 Beachrock Analysis

EDX is used to determine surficial elements of the selected beach rock samples and EDX-SEM was performed to observe the surficial cementation properties of beachrock.

### 3.2 Formative Environment - Sea Water Analysis

$[Ca^{2+}]$ was determined using an EDTA titration. AAS analysis was done to determine $[K^+]$ and $[Na^+]$ and Ion chromatography analysis was performed to determine anion content; $[Cl^-]$ and $[SO_4^{2-}]$.

## 4. Results and Discussion

### 4.1 Formative Environment Analysis - Sea Water Analysis

Results of the sea water analyses are presented in Figure 2, 3 and 4. The results obtained from sea water analysis were compared with the average global seawater concentrations [2].

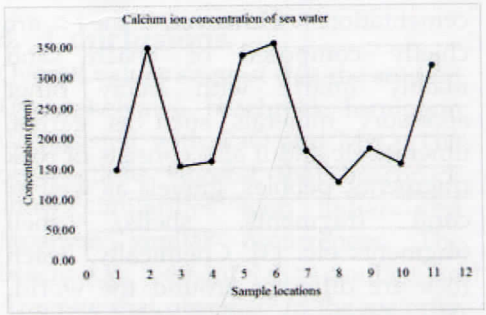


**Figure 2 - $[Ca^{2+}]$ concentration of sea water**

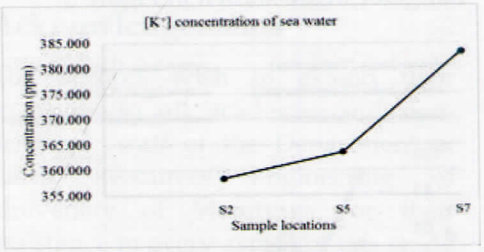


**Figure 3 - $[K^+]$ concentration of sea water**

Average global $[Ca^{2+}]$ percentage is 200-410 ppm and the calculated values are in between the global values as shown in the Fig. 2. Observed $[K^+]$ concentration is between 350- 390 ppm which is in the range of global average value of 390 ppm (Fig. 3).

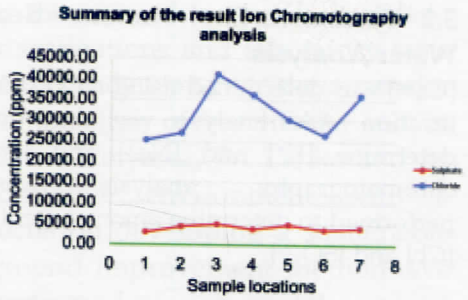


**Figure 4 - [$Cl^-$] and [$SO_4^{2-}$] concentration of sea water**

[$Cl^-$] and [$SO_4^{2-}$] concentrations (Fig. 4) are above and below the global concentration, 19,400 ppm and 8,980 ppm respectively.

## 4.2 Beachrock Analysis

Beach rocks consists of any material in beach sediment at the moment of cementation. However, they are chiefly composed of beach sand mainly quartz with many other accessory minerals such as garnet, ilmenite etc and it also consists of rock fragments, pebbles, gravels as well as coral fragments, shells/ shell fragments etc. [3]. Chemically, beach rock are different around the world. The difference of main chemical composition in India, Japan, and Bangladesh are shown in Figure 5.

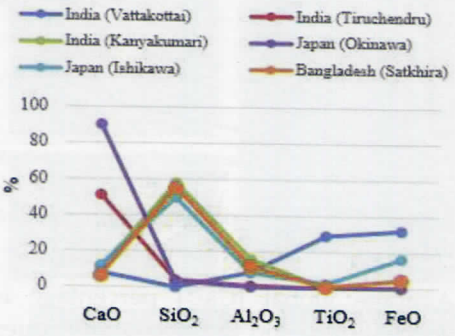


**Figure 5 - Beach rock composition [4]**

### 4.2.1 Elemental Analysis

Surficial environment of the beachrocks were analysid using EDX. Samples analysed were composed mainly of CaO, and MgO (Fig. 6). Meanwhile, samples contained many elements, including $Al_2O_3$, $SiO_2$, $K_2O$, FeO, and $TiO_2$.

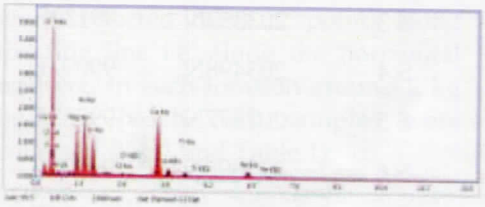

**Figure 6 - Results of EDX analysis_S12**

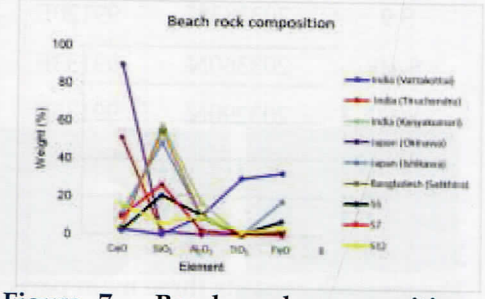


**Figure 7 - Beach rock composition including composition of Uswetakeyyawa beachrock**

Uswetakeiyawa beachrock composition shows significant similarities with the other countries like India and Japan (Fig. 7). Ferrous and Titanium content in Uswetakeiyawa beach rock is almost same as Okinawa, Japan and Satkhira, Bangladesh. Si content in Uswetakeiyawa, Sri Lanka is comparatively lesser than beachrock at Kanyakumari, India.

### 4.2.2 SEM Observations

To observe the beachrock surface and to identify the cement of beachrock EDX-SEM. Beachrock cements can be mainly calcitic or aragonitic [5] depending on the physicochemical

parameters (e.g. temperature, salinity, pH and the abundance of Mg) of the diagenetic environment [5]. SEM image of S12 (Fig 8) show a needle like cementation between the grains of the samples. This might be the Arogonite cementation(polymorphs of $CaCO_3$) which normally shows this type of needle structure.

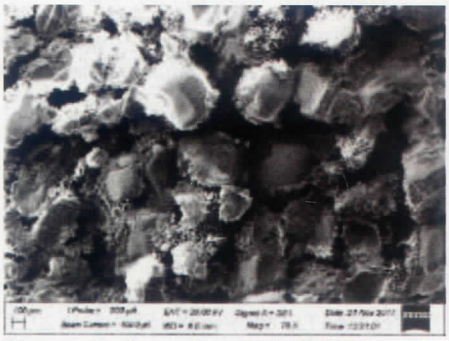

**Figure 8 - Location S12_SEM image**

When consider the Mg and Ca compositions, if Mg percentage is greater than Ca, then the particular material is said to be consisted with High Mg calcite(polymorphs of $CaCO_3$) [2]. In the samples tested under EDX, CaO< MgO. Hence this beachrock might consist of Aragnite cement which is also showed in SEM images. This results should be further strenthend by performing a X-ray Difraction Analysis.

Figure 9 shows the compositional distribution beachrock in 77 sites around the globe [2]. This shows that the cements at 75 out of the 77 sites worldwide were polymorphs of $CaCO_3$

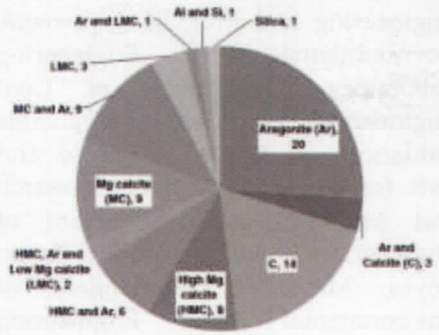


**Figure 9 - Beachrock cement mineralogy and number of sites with a given mineralogical composition among the 77 sites reported worldwide**

Therefore, the beachrock cement at Uswetakeyyawa,Sri Lanka is similar to that observed in the majority of the sites globally.

## 5. Conclusions

Overall values suggest that the studied Uswetakeiyawa beachrock formation is consisted with CaO and MgO. The observations suggest that beachrock show similarities with Indian and Japanese similar occurrences. The beachrock cement is similar to Aragnite that observed in the majority of the sites globally.

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## References

[1] DeJong, J., Mortensen, B., Martinez, B. and Nelson, D. (2010). *Bio-mediated soil improvement. Ecological Engineering*, 36(2), pp.197-210

[2] Danjo, T. and Kawasaki, S. (2014). *Formation Mechanisms of Beachrocks in Okinawa and Ishikawa, Japan, with a Focus on Cements. Materials Transactions*, 55(3), pp.493-500.

[3] Wagle BG (1990) *Beach rocks of the central west coast of India*. Geo-Mar Lett 10(2):111–115

[4] Md. Nakibul Hasan Khan, Takashi Danjo and Satoru Kawasaki (2015), *Artificial beachrock formation through sand solidification towards the inhibit of coastal erosion in Bangladesh International Journal of GEOMATE* 9(2) 1528-1533 Dec 2015

[5] M. I. Vousdoukas, A. F. Velegrakis and T. A. Plomaritis, *Beachrock occurrence, characteristics, formation mechanisms and impacts*, Earth-Science Rev. 85 (2007) 2346