Performance Forecasting for the Beach Nourishment Project at Palliyawatta-Uswetakeiyawa Sri Lanka

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Abstract: Beach nourishment is a soft engineering solution that is increasingly used to combat erosion in a sustainable manner. Sri Lanka's first major Beach nourishment project was carried out over a 1.8 km stretch in the UswetakeiyawaPalliyawatta area, by the Coast Conservation Department of Sri Lanka (CCD). The Project was conducted in January 2012 and 300,000 cubic meters of offshore sand pumped using a dredging vessel was used to nourish the stretch of eroded beach with a total project cost of USD 300 million. This research was carried out to assess the performance and to forecast the future performance of the above nourishment project. Topographic data and grain size data were gathered and analyzed over a period of six months spanning an entire seasonal cycle. Satellite imagery spanning a much larger time period were also analyzed and complemented with the field data. The findings of the research indicate that due to incorrectly oriented sand retention structures and the incorrect grain size of nourished sand, the nourished area is currently undergoing rapid erosion. However, it is forecasted that the beach will come back to its pre-nourished stage after a period of 12 months. This will result in the exposure of a beach rock at the mean sea level and will cause the beach to lose its recreational and aesthetic value, and to prevent this and to retain the nourished sand, the correct orientation of the retention structures and the appropriate grain size for nourishment are proposed.

Key Words: beach nourishment, erosion prevention, performance forecasting, Uswetakeiyawa Sri Lanka

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1. Introduction

Sri Lanka being an island country relies heavily upon its coast for both economic and recreational activities. Coastal Erosion presents as a major challenge in this regard and the Coast Conservation Department (CCD) was established in 1983 to undertake coastal protection and management schemes in Sri Lanka. Keeping in line with this objective, Sri Lanka's first beach nourishment programme was carried out over a 1.8km stretch in the Uswetakeiyawa-Palliyawatta coast in January 2012.One year after the nourishment, a set of detached breakwaters had been constructed to protect the nourished stretch. The performance of a beach nourishment is largely site specific and will vary with different conditions present at different regions. (van der Wal., 1998). Therefore, a proper assessment of the impact and the development of a performance forecasting model will have to incorporate relevant site data and it will have to be carried out with reference to climatic, geologic and seasonal changes of the region. This project concerns mainly with the stretch of nourished beach at Uswetakeiyawa, and aims to assess the extent of erosion and the effectiveness of the nourishment and the associated retention structures. While similar studies have been carried out in many parts of the world (Ells et al 2012, Castelle et al 2009, Hartlog et al 2008, Elko et al 2005), no such research has been performed in Sri Lanka. This study assesses the beach profile evolution, sand volume changes and the effects of grain size on the nourishment programme. Care has been taken to involve the effects of the monsoon cycle and other relevant factors. Using the information derived from data analysis, suitable recommendations have been provided. These can be used for beach nourishment programs of similar capacity, in other parts of the country.

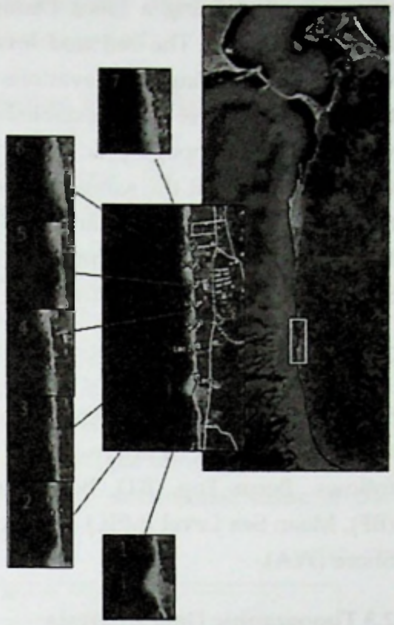

Figure 1:The Study Area Palliyawatta-Uswetakeiyawa Sri Lanka

2. Methodology

2.1 Beach Topographic Survey

A topographic survey was carried out over a 1 km stretch over the nourished area. Landmarks corresponding to the ones identified in the preliminary map analysis were located and the survey lines were determined and marked permanently (Fig 1).

Level surveys were carried out along 7 transects spaced at 150 m interval and perpendicular to the beach at the determined locations, with back sights at the permanent stations. The dry beach was surveyed using a Leica Total Station instrument and the near shore zone below the mean sea level was surveyed using a Leica Dumpy level instrument. The reduced levels were found by tying the elevations to the Mean Sea Level (MSL),established visually. The topographic surveys were conducted at the same locations that were permanently marked over four field visits spanning from September 2014 to March 2015.

2.2 Sampling

Sand samples were gathered at each transect at specific locations named as follows. Berm Top (BT), Berm Face (BF), Mean Sea Level (MSL) and Near Shore (WA).

2.3 Topographic Data Analysis

The gathered topographic data was processed to provide distance elevation variations and the results were tabulated. The calculations were performed on a spreadsheet. Once processed, the elevation data was exported into Surfer and the 3D surface of the coast was prepared for each visit. The volume of sand above the Mean sea level (identified by z=0 level) was calculated for each field visit and the sand volume changes were calculated. The beach width and beach profiles were also extracted using this processed data. The elevation data were plotted to identify the beach profile evolution.

2.4 Particle Size Analysis

The samples collected were air dried for 48 hours and dried in the oven at 105° C for 24 hours. Dried samples were cone and quartered to 500 g, and sieved using a standard set of Sieves, with sieve sizes ranging from 2000 to 75 microns. The results were entered into the GRADISTAT package(Simon Blott, 2010) and the mean grain size (Arithmetic Mean) was calculated and extracted for analysis.

2.5 Satellite Imagery Analysis

Google Earth images were used to derive the beach widths over a longer time span, covering the nourishment programme and the construction of

the breakwaters. To extract beach width data, a baseline was constructed on the master image from which all measurements were taken. Distances from this baseline were calculated in images taken at different time periods revolving around the nourishment program.

3. Results and Discussion

3.1 Beach Profile Evolution

Apart from the general sand transportation taking place due to the monsoonal changes, several other trends were identified. Several profiles showed a convergence with time and evolved into a step-like pattern towards the last visits. This signifies the exposure of the beach rock that lies at the mean sea level at the study area. Due to this exposure of the beach rock, it is seen that further erosion is hindered as it acts as a natural sand retention structure. It is also seen form the profiles that they gradually become less steep and thus are approaching a state of equilibrium. In addition it was also seen that some locations have showed

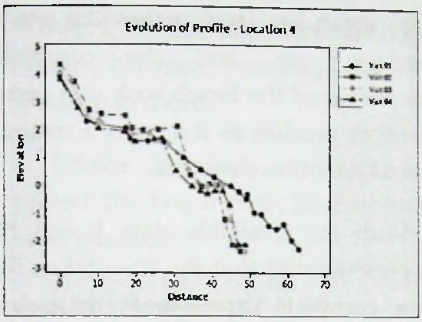

Figure 2: Profile evolving to a step like pattern

significant sand accretion, by their elevated profiles, while some showed significant erosion.

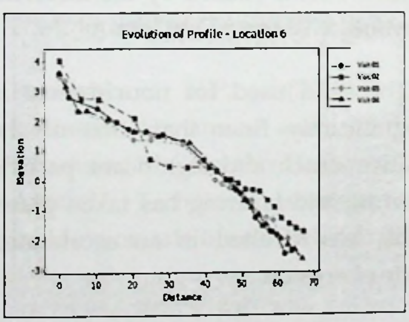

Figure 3: Stabilizing Profile

3.2 Sand Volume Changes

The sand volumes show a gradual but steady decrease accompanied by an increase in the last visit. This increase is attributed to the natural sand accretion during the fair weather accompanying the North Eastern monsoon period.

However, this increase does not bring the sand volume to its original amount and the data shows an overall decreasing trend. This signifies a net erosion. The trend-line associated with this data was used to calculate the approximate time for the entire beach rock to be exposed. This period is 12 months. Thus after this period, it is assumed that the erosion would stabilize although resulting in the loss of recreational value of the beach.

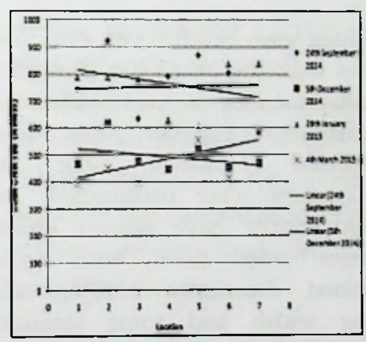

Figure 4: Grain size variation at MSL

3.3 Particle Size Analysis

Both the Mean Seal level and Surf zone mean grain sizes indicate an increasing trend during two visits and a decreasing trend during the other two visits. This signifies a change in longshore sediment transport direction and is consistent with the longshore current directions created by the South Western and North Eastern monsoons respectively.The analysis of the cross shore particle sizes shows that the nourished sand (found in berm top) is significantly finer than the original sand at the beach. This difference in average particle size between the nourishing sand and the original beach sand affects the performance of nourishment significantly. It is generally accepted that the nourishing sand should be approximately equal to or coarser than that of the native beach.

Table 7 : Cross-Shore Grain sizes

	Loc 1	Loc 2	Loc 3	Loc 4	Loc 5	Loc 6	Loc 7
Berm Top	522.8	580.9	407.3	469.5	548.0	692.4	474.5
MSL	744.3	923.3	633.9	793.5	869.0	805.6	584.0

3.4 Beach Widths from Satellite Imagery

The long term beach width evolution shows that, the beach has showed a gradual increase in width after the nourishment program has been completed. However, after the breakwaters were constructed, the beach widths have shown erratic changes over time, with some locations drastically eroding and losing width and some locations accreting and gaining drier beach. This indicates that the breakwaters constructed are of incorrect layout and dimensions and thus are not effective.

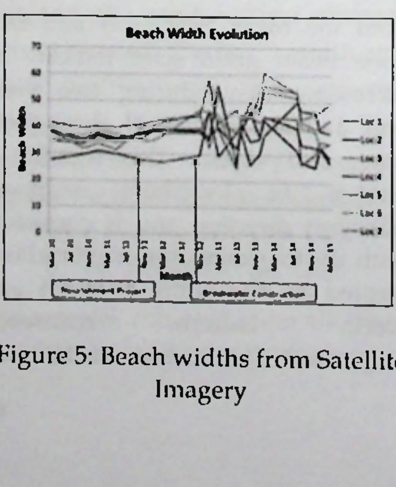

Figure 5: Beach widths from Satellite Imagery

4. Conclusions

The following conclusions can be made;

• The occurrence of a beach rock at the mean sea level makes the site a unique one, and the complete exposure of the beach rock will cease further erosion as it acts as a natural sand retention structure.

• With the available data it can be approximated that the time taken for the complete exposure of the beach rock is about 12 months.

• The detached breakwaters constructed to protect the nourished sand have not been effective and it has resulted in an erratic changes in beach widths caused by the incorrect layout.

• The sand used for nourishment is significantly finer than that of the native beach and significant particle sorting and layering has taken place. This has resulted in an accelerated rate of erosion.

• The sediment movement at the site is bi-directional and the current breakwaters are not effective against it. Structures that are suitable in such cases will be more effective in protecting the nourished sand.

The following recommendations are provided to rectify some of these problems;

- Proper and periodic re-nourishment with a mean grain size of about 850 to 900 microns.

- Breakwaters with the following design criteria are suggested. L > 150 m Lgap< 40 m, Assuming D=50. Where, L - length of breakwater, Lgap - gap between breakwaters, D - distance to shore.

- Groins installed at shore will protect the beach from bi-directional sand transport.

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