A Field Experiment for Coastal Dune Reconstruction

Tsung-Yi Lin　　Jiing-Yih Liou

ABSTRACT

Coastal dunes, as a whole, represent a natural barrier between the sea and the land, playing a vital role in the coastal defense against the waves and tides. Compared to the use of hard, man-made structures, not only is it a less expensive method to counteract the coastal erosion problems, but it is also a method that has higher ecological and scenic values in the environmental management aspect. In this research project, a field experiment was conducted for dune reconstruction at the Ching-tsao-lun reach of the Tainan coast where the foredunes had been eroded and washovered by a previous typhoon. Three experimental sets were put up to re-build foredunes that have been previously damaged, and a small natural remnant dune was chosen as the comparison set for evaluating the effectiveness of the reconstruction of foredunes. The dune building processes were observed by monitoring the changes of dune profiles, surface sand grain size, and the vegetation density. The experiment results are used to create an appropriate dune rehabilitation suggestion for this area. The results reveal that a bulldozed artificial dune can raise the dune height immediately, and putting racks on the bare sand surface can help the accumulation of sand and the colonization of vegetation that will quickly stabilize the artificial foredune.

Keyword : Dune reconstruction; Vegetation rehabilitation; Sand fence accumulation; Artificial dune

1 INTRODUCTION

Aeolian dunes are landforms that are common along the western sandy coast of Taiwan (Shih et al., 1993). They are found above the high water marks of sandy beaches (Carter et al., 1990). In fair- weather conditions, the exposed dry sand deposits on the backshore are the main sources for the aeolian dune deposits. The dunes are predominantly composed of loose, sand-sized sediments that allow the dunes to adjust their landforms in response to coastal processes. Shore-parallel foredunes plays a vital role in the coastal defense against the waves and tides by acting as a natural barrier between the sea and the land. In comparison to the hard, man-made structures, such as sea walls, groins, and detached breakwaters, that are usually used in Taiwan to counteract the coastal erosion problems, the reconstruction of coastal dune is considered to be a less expensive method that has higher ecological and scenic values in the environmental management aspect. In European countries and the U.S., for example, the constructions of artificial coastal dunes or the reconstructions of damaged natural dunes have long been employed as a defense mechanism (Carter, 1988). Taiwan, on the other hand, still lacks concrete experience with the methods of dune construction. Thus, in this research project, a field experiment was conducted for dune reconstruction at the Ching-tsao-lun reach of the Tainan coast where the foredunes had been eroded and washovered by a previous typhoon. Observations are made regarding the morphological developments in different experiment sites; they are used not only in investigating

National Taiwan Normal University, Taipei, Taiwan, R.O.C.
Email: aeolin@cc.ntnu.edu.tw　(Tsung-Yi Lin)

effective methods of coastal dune reconstruction, but also in providing other parts of Taiwan with new ideas concerning the defense strategies chosen for other coastlines with dunes.

There are many methods that can be applied to re-build destructed dunes, such as accumulating sand by using sand fences, seeding or planting different vegetation species to help accumulating sand, or artificially building the dune forms that are previously determined to be needed. Questions as to which methods will be the best fit for the specific coastal conditions, questions as to how sand fences should be deployed, as well as questions as to how appropriate vegetation species are chosen or where to the sand sources for artificial sand building are found, are to be answered.

2. FIELD EXPERIMENT

Three experimental sets representing the applications of three different methods used by other countries (sand fences that retain accumulation of sand; the seeding or planting of different vegetation species; the building of artificial dune forms that are specifically designed as needed) were set up as part of the field experiment. A small natural remnant dune was selected, so that comparison can be made in order to evaluate the effectiveness of the foredune reconstructions. The setup was finished in summer of 2006, and the one-year observations had since begun. Dune developments were monitored for changes found in categories, such as dune profiles, surface sand grain size, and vegetation density, to assess the efficiency of dune reconstruction and to observe the dune building process. An appropriate suggestion for dune rehabilitation in this area is formed by combining experimental results and conclusions.

2.1 Field Experiment Deployment

Experimental sets, each being 50 meters long along the shore and 20 meters into land, are selected according to their landforms and vegetation conditions. These sites are all located at backshores above the average high water level and are surrounded by ropes and signs to keep people from intruding and interfering with the field experiment.

Set A (Figure 1 top left) is the area for artificial planting of different vegetation species. The three vegetation species chosen for the experiment are the prevailing species in this area that have been investigated by a previous project (Huang, et al. 2006). After planting or seeding the plants, irrigation is made available every other day to boost the growth of these plants in the first three months. The whole set area is divided into two halves, the front half being covered by grids of discarded bamboo-made racks (that were used to breed oysters). These racks are found to have collected upon the beach after a previous typhoon. This setup is used to examine whether these discarded materials can help the growth of dune vegetation.

Set B (Figure 1 top right) is the natural dune site acting as a control that the other experimental sites can compare to. Nothing is inflicted upon this area except that it is roped off so that there would not be any intruders.

Set C (Figure 1 bottom left) is the area of synthetic dune forms constructed from sand intermixed with broken oyster shells that have already been on the beach. A bulldozer is used to pile sand upon the backshore into a dune approximately 2.5 meters high, half of it being left bare and the other half being covered by racks.

Set D (Figure 1 bottom right) is the area that was fenced by using materials available there. The fencing is arranged in an L shape to influence the air flow, thus instigating the accumulation of sand carried by the wind. The southern side, which faces the southwest wind directly, is built to be the longer side, while the eastern side is the other shorter side. Each fence is approximately 1.2 meters high, and the fence porosity is 25%.

2.2 Field Experiment Deployment

The four experimental sets described above each yielded changes that were monitored during the experimental period, such as dune profile, surface sand grain size, and vegetation density. Dune profile changes are monitored by setting up three survey lines for each set, creating a total of 12 survey lines (Figure 2). In each set, the lengths between each survey line are 20 meters each. Benchmark poles were set up for each profile ,and the profile measurements were made each month. The survey line extended from high water level to the back of dunes.

Sand samples also collected along the profile survey lines. Only the most upper 1cm sand of the surface was collected. The frequency of sand sample collecting is once a month. Meanwhile, the vegetation conditions in the four experimental sets were evaluated by investigating the vegetation species and their cover lengths. There were four 20-meter vegetation survey lines in each experimental set.

Fig1. The four experimental sets in the Ching-tsao-lun Field

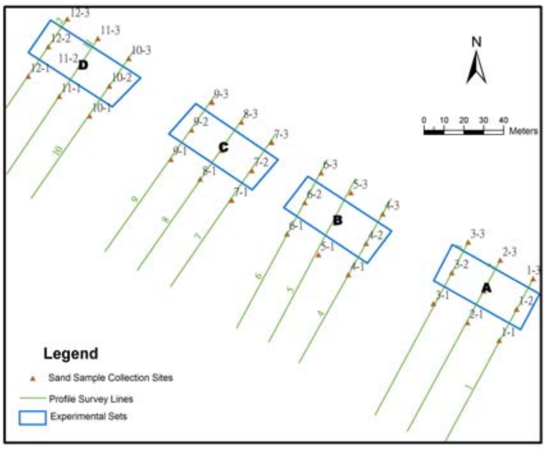

Fig2. A field deployment index for profile survey lines and sand sample collection sites.

3. RESULTS AND DISCUSSION

3.1 Cross-section Profiles

After setting up the four experimental sets, the original cross-section profiles were measured.The results of the monthly surveys shown that during the first three month (July-September),each experimental set had sand accumulation (Figure 3). Erosion occurred only in the bare half of the artificial dune. In set A, the sand sediment accumulated near the racks and vegetation (no matter it is natural or artificial). The sand accumulation sites in set B and set D matched with the well-covered vegetation sites. Sand accumulation in set C occurred in the half that was covered with drafting wood and bamboo racks. Field observation found that sand accumulated very fast in the early stage, but the accumulation rate greatly slowed down until it be came stagnant as the sand surface level reached the height of these debris.After October, most of the experimental area began to erode (Figure 4), rare sand accumulated except the fore dune slope of set C.These sand were blown from the flat, bare half of the articial dune.

3.2 Surface Sand Sample

The grain size of sand sample shown that the median grain size of these samples collected is between 0.191mm and 0.209mm. Most of the samples are fine sand and are well-sorted. The grain size of the modal class is 0.185mm~0.203mm, which is the favorable sand size for aeolian transport in this area. In some samples, a small peak appeared near the 0.6mm grain size in the sand distribution graph. This is probably due to a mix up with sand transported by wave action.

The variations in median grain size for each month during the one-year period reveal that, in most of the samples, the grain size did not change much. A larger grain size variation only occurred in small amounts of samples, and most of them happened either in September or October. This result may indicate a variation of aeolian processes, such as changes of wind direction and sand transport ability in these two months.

3.3 Vegetation Investigation

Without the interruption of severe typhoons during the monitoring year, the overall results of the vegetation investigation show most of the vegetation species had grown well during the the period, especially in the summer season. The growth of vegetation is fast during the summer and became slower and more stable as the month of October approaches. Two major species of plants were found in the experimental field, the Ipomoea pes-caprae and Spinifex littoreus. Each species composed about 31 percent of all vegetation. Some other plant species, such as Canavalia rosea, Panicum repens, and Bidens pilosa var. radiata were also presented.

In the artificial plating set (set A), both Ipomoea pes-caprae and Spinifex littoreus grew well (Figure 5), but the other one species, the Sesuvium portulacastrum did not grow. In the natural vegetation set (set B) and the fenced set (set D), both natural Ipomoea pes-caprae and Spinifex littoreus grew well. The variations of vegetation cover, however, show that the Spinifex littoreus became the prevailing species during the dry season in October. This may imply that Ipomoea pes-caprae may need irrigation to assist the continuous growth and wider distribution. The artificial dune set (set C) had no vegetation at the first beginning, but new growing buds of Canavalia rosea and the intrusion of Ipomoea pes-caprae were found in the second month. Both species grew steadily and gradually dispersed to cover the original bare surface. However, the Spinifex littoreus was not found in this set during the monitoring period.

3.4 Discussion

Putting together the survey analysis above, it is apparent that, except for the bare section of the artificial sand dune site (set C), all the sets yielded, in general, a growth in accumulation of sand during the summer months of July, August, and September, due to the onshore winds and the beach sand source. The vegetation and racks also help in retaining the sand deposits. The direction of the seasonal winds changed from onshore to offshore after October. The offshore winds were weakened by the windbreak forest before reaching the dune area. Although there was not much accumulation, the vegetation cover on the dune surface increased. The weakened offshore winds can only created some small area of blowouts that did not fully covered by vegetation. The bare section of set C, for example, had greater amounts of sand piled in the front edge of the set, which is evidently accumulating on the foot of the foredune slope. An obvious wind erosion zone is also found on the backshore area.

The original vegetation covers in set B (the natural vegetation set) increased in summer and helped accumulate sand, but the increase rate is less than the irrigation area in set A. The vegetation covers decreased somewhat during the dry, winter season in set B, which resulted in higher offshore wind erosion compared to set A. The growth pattern of two different vegetation species, Ipomoea pes-caprae and Spinifex littoreus in set B may be due to their different adjustment ability to the seasonal climate change.

Without any erosion caused by typhoon waves, the artificial dune in set C maintained its height. Both the front and back slopes were smoothed due to sand slumping and accumulation on slopes. The bare half of set C served as the path of wind-blown sand that allowed sand to temporarily accumulate, but these sand were blown away later. The shell pavement was formed in the first several months. Goinginto later stages, the vegetation species, such as Ipomoea pes-caprae intruded into the bare area, and reduced the offshore wind erosion during the winter. The other half of set C is paved by drifting wood and bamboo racks. It helped in accumulating sand quickly in the early stages, which resulted in an obvious step structure was formed at the boundary of these two parts of set C. The seeds of the species Canavalia rosea were buried in sand when the artificial dune was constructed. They grow very quickly in the rack-covered half, but could not be found in the bare half. The sand accumulation function would then cease when the sand level reach the height of rack.

Set D is assigned for the sand fence accumulation experiment. There are many parameters that could affect sand accumulation, such as fence height, porosity percentage, wind direction and material used for fencing. Generally, the effective distance for sand accumulation is about eight times of the fence height. For example, a one-meter fence will result in sand accumulation in a distance of 8 meters downwind (French, 2001). The morphologic rises due to aeolian sand accumulation in profile 10 and 11 are in approximately this distance. The overall sand accumulation in this set did not fulfill the expectation. The main reason could be the fence porosity. The original design of the fence porosity is 30%, as with Kuriyama et al., (2005), but the real set-up fence is only about 25%. With the fence setting up in an L-shape to cover the sides of the experiment area, the paths of the winds that are actually effective for sand transport may not be perpendicular with the fence, so the practical fence porosity will decrease.

Hotta et al. (1987) suggest that a minimum of 50% fence porosity is needed for better sand accumulation.

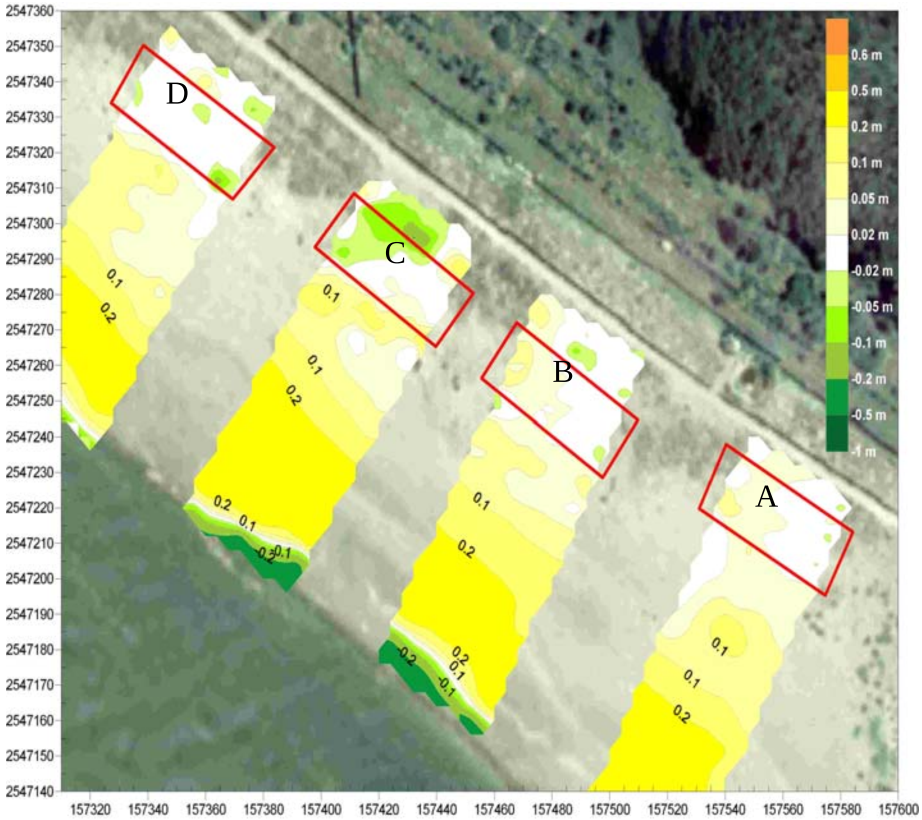

Fig3. The morphological changes during the summer of 2006 (2006.07~2006.09)

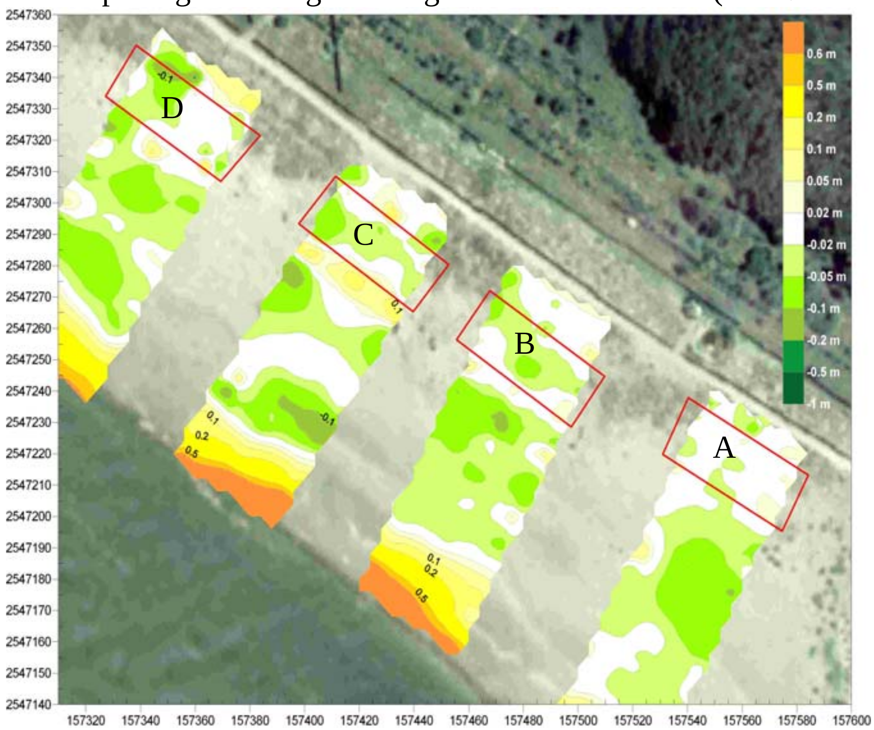

Fig4. The morphological changes during the winter of 2006-2007

Fig5. The vegetation growth in the artificial planting set

Fig6. The vegetation growth in the rack-coverd side of set C

4. CONCLUSIONS

After one year of field experiment, several conclusions could be made.

(1) Aeolian transport activities are controlled by the changes of monsoon winds. During the summer season, the prevailing southwestern winds blew dry beach sand inland. Dunes grew larger due to accumulation of aeolian sand. The prevailing winds in winter season are the offshore winds that are weakened by the windbreak forest inland. Only surfaces that were not covered by vegetation have faced dune erosion. As long as there are no severe wave erosions caused by typhoon waves, dunes in the research area would grow a little larger each year.

(2) Vegetation species Ipomoea pes-caprae and Spinifex littoreus grew very well after planting, and they were helpful in sand accumulation. Compared with natural vegetation, this artificial vegetation reveals that irrigation may help its growth, especially during the dry winter season. The irrigation may benefit Ipomoea pes-caprae the most. Pavements of gridded racks also helped the vegetation seeds to bud and grow.

(3) Artificial constructions of sand dune could raise the dune height immediately. To help stabilize the dune surface, artificial seeding or planting that increases the vegetation cover is recommended. Pavements of discarded bamboo racks on the bare dune surface could help accumulate sand in a faster pace, but when the sand surface reaches the height of the racks, the accumulation function cease to work.

(4) The sand accumulation at the sand fence set did not fulfill the expectation. This may be due to the low porosity percentage. For better results, a minimum of 50% fence porosity may be needed.

(5) Based on the coastal security aspect, the southern part of Ching-tsao-lun reach, where the field experiment carried out, is a relatively stable coast. It may not need any anthropogenic action on reconstructing the dunes. From the dune management point of view, however, reinforcement of sand dunes with artificial plating or seeding could help sand accumulation and increase ecological and scenic values.

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