Effect of Bent Flexible Vegetation on Fluvial-bed Change under Flood Conditions

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INTRODUCTION

The frequency of heavy rains and typhoons caused by climate change is increasing in recent years. Rains and typhoons cause a lot of sediments to move from mountains, hills, and plains into rivers and often result to serious sediment disasters. Therefore, understanding how sediments are transported in rivers is crucial. Generally, the existence of vegetation can change the flow conditions and the sediment transport characteristics of a river. In some extreme weather events, when a flood caused by rainfall or typhoon event sweeps past the riparian vegetation communities on the sandbank, stream-side, and floodplains, its high-sediment-concentration current will cause a series of complicated interactions with the vegetation. In previous research work, researchers have designed a series flume experiments to understand the interactions among the vegetation, current, and sediments. Most flume experiments used model vegetation with different artificial density (single or multiple), arrangement (staggered, columnar, or aligned), and rigidity (rigid, flexible, or mixed) to simulate the situation of a natural river. Moreover, most of these flume experiments are focused on the normal flow conditions (i.e. experimental velocity is less than the critical velocity and there is no sediment input during the experiment). Flood conditions are rarely discussed. Therefore, a series flume experiments were designed to observe the effects of vegetation during floods.

METHOD

The experiments were conducted in a 15m length by 0.6m width, glass-sided recirculation flume system. The vegetation models which were made of flexible plastic material were arranged in the bed area at 2m long by 0.6m wide. Individual vegetation model was arranged on grid points randomly determined by their X and Y coordinates on a 1 cm x 1 cm grid system drawn in this area. The vegetation was arranged at a 22° angle. Three vegetation densities were tested: 33.33 (test 1~3), 66.67 (test 4~6), and 100 (test 7~9) stems/m^2. Each density was triplicated, although each replicate was with a different random distribution pattern as described earlier. A test began by running water continuously through the flume for 10 hours. A water flow rate of 0.03 m^3/s was set to give an initial velocity of 0.5 m/s to simulate flood conditions. Concurrently, the quartz sand was allowed to drop continuously at a rate of 0.35 kg/min from a sand-supplying device located at the beginning of the sand area.

RESULT AND DISCUSSION

To understand the effects of vegetation on sediment transport in the fluvial-bed, we compare the amount of fluvial-bed sediment change before and after a test. The results are shown in **Table 1**. The amount of sediment increases in the upstream area, mainly due to the blocking effect of vegetation. If the current is blocked by obstructions, part of the kinetic energy will be converted to potential energy and cause the phenomena of flow velocity decrease and water level increase. These phenomena can promote the sediment to deposit in this area and to form the depositional bed. As the vegetation density increases, the sediment which is blocked by vegetation also increases. In the vegetation area, the amount of sediment is increased in the 33.33 stems/m^2 and 66.67 stems/m^2 tests. However, the amount of sediment is reduced in the 100 stems/m^2 tests. This change is caused by the vegetation's effects of concentration and blocking. As the vegetation density increases, the influence of concentration effect will be greater than the blocking effect. Therefore, the fluvial-bed changes from depositional to erosive in the vegetation area. Finally, the amount of sediment is always decreased in the downstream area. The reason is that the current above the vegetation can deflect to downward when leaving the vegetation area. This deflective current can scour the fluvial-bed, so the amount of sediment is decreased in the downstream area. A special feature is that the erosive amounts, 30 kg and 28 kg, are not obviously different between the 33.33 stems/m^2 and 66.67 stems/m^2 tests, respectively. Moreover, it reduces to 16 kg in the 100 stems/m^2 tests. The reason for this difference is that the fluvial-beds of vegetation area are depositional in the 33.33 stems/m^2 and 66.67 stems/m^2 tests, so the downstream fluvial-beds are only affected by the deflective flow to scour. Nevertheless, the fluvial-bed of vegetation area is erosive in the 100 stems/m^2 tests, such that the downstream fluvial-bed is not only scoured by the deflective flow but also gets a supplement of sediments from the erosive vegetation area to slow down the scouring.

CONCLUSIONS

From the results, we can conclude that the upstream fluvial-bed is always depositional and the downstream fluvial-bed is always erosive. However, the fluvial-bed in the vegetation area changes from depositional to erosive as vegetation density increases. The phenomena show that the denser the vegetation in a river does not imply better conditions. If the amount of vegetation exceeds the maximum river capacity, the vegetation does not stabilize the riverbed and it further increases the degree of riverbed erosion. The findings from this study are of paramount importance in river management.

Tab. 1 Amount of fluvial-bed sediment change

Density (stems/m^2)	Upstream area (kg)	Vegetation area (kg)	Downstream area (kg)
33.33	+5.01	+27.52	-29.86
66.67	+15.50	+1.43	-27.79
100	+28.18	-29.26	-16.23

Note : + means deposition; - means erosion

Keywords: Vegetation, Flood condition, Fluvial-bed change