Roles of Riparian Vegetation on Shoreline Deposition/Erosion Relief

Jin-Hong Kim

***Abstract*—** Roles of riparian vegetation on erosion relief of the stream bed or on deposition of the fine sediments along riverfront by the species of the aquatic plants were presented. Field investigation on the estimation of the change of the bed level and the flow velocity were performed. The results showed that *Phragmites japonica* has function of erosion relief of 0.3m-0.4m in the range of higher than 1.0m/s of flow velocity at the vegetated region. *Phragmites communis* has role of erosion relief of 0.2m-0.3m higher than 0.7m/s of flow velocity. *Salix gracilistyla* has greater role than *Phragmites japonica* and *Phragmites communis* to sustain the stable channel. It has the mitigation function of 0.4m-0.5m of the erosion in the range of higher than 1.4m/s of flow velocity. *Miscanthus sacchariflorus* has a weak role compared with that of *Phragmites japonica* and *Salix gracilistyla,* but it has still function for sustaining the stable bed. From these results, the vegetation has effective roles of erosion relief or deposition of the stream bed.

***Keywords*—** Riparian vegetation, deposition, erosion relief

I. Introduction

VEGETATION in the river is affected by the flow structure, but inversely affects the flow. It is impacted and damaged by the high tractive force of the river flow during flood, but it reduces the velocity of river flow.

Vegetation impact by the flow was studied by several scientists. Kim [1] showed that most of the aquatic plants except for *Salix gracilistyla* were bent and destroyed by the flood flow, and moreover *Salix gracilistyla* was even destroyed when the scrubs and the floating trashes were caught in it since they enabled to make higher the dynamic pressure of the flow. He suggested that vegetation behavior was classified into 4 stages of stable, recovered, damaged and swept away. Criteria between recovered and damaged stage was determined by the bending angle of the aquatic plants. Miyazaki et al. [2] studied about the river hydraulic examination which considers the dynamic characteristics of reed community at the time of the flood. Vegetation impacts in a degraded gravel-bed river were studied by Shimizu et al. [3]. They evaluated the maximum size of the movable gravels and the local bed degradation based on the field study and the numerical calculations with 2D-flow model.

Jin-Hong Kim is with the Dept. of Civil & Environmental Engineering, Chung-Ang University, Seoul, 156-756, KOREA (phone: 82-2-820-5893; fax: 82-2-812-6397; e-mail: jinhkim@cau.ac.kr).

Transport of the bed sediments during the flood seasons resulted in the deposition of the vegetated area and the vegetation may be buried and damaged. Thus, the flow characteristics and the riverbed sediments affect the vegetation impacts.

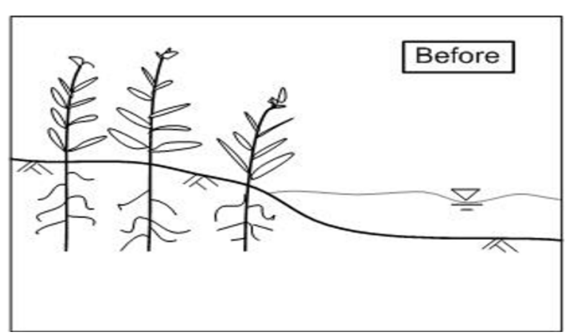
On the other hand, vegetation inversely affects the flow structure. The presence of vegetation modifies flow and sediment transport in alluvial channels and hence the morphological evolution of river systems [4]. Aquatic plants increase the local roughness, modify flow patterns and provide additional drag, decreasing the bed-shear stress and enhancing local sediment deposition or erosion relief [5]. Thus, the vegetation and flow structure has mutually reciprocal relationships [6].

Vegetation impacts by the flow structure are studied well, but studies on the flow effects by the vegetation itself are few. The purpose of this study is focused on the latter. This paper presents the role of the riparian vegetation on erosion relief or deposition of the fine sediments at the river front by the species of the aquatic plants.

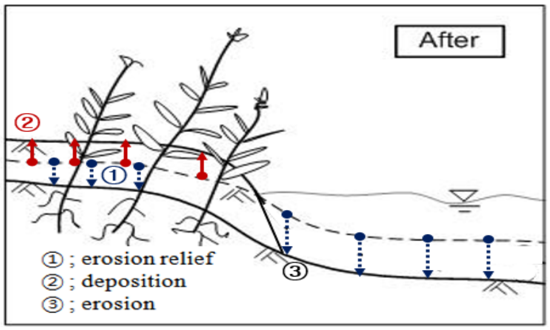
Field investigation on the estimation of erosion/deposition of the stream bed using the reinforced bar staff and measurements of the flow velocities were performed to determine roles of the vegetations by the species of the aquatic plants.

II. Variation of Stream Bed by Aquatic Plants

Variation of the stream shoreline before and after flood is shown in Fig. 1. In Fig. 1(b), the dotted line corresponds to bed profile before flood and the solid line corresponds to bed profile after flood.



(a)



(b)

Fig. 1 Variation of stream bed before (a) and after (b) flood

Variation of the stream bed after the flood at the vegetated area may be two cases. One is the eroded case when the flow velocity is high. It corresponds to erosion mitigation by the function of the aquatic plants. The other is the deposited case when the flow velocity is comparatively low. The eroded case occurs only outside the vegetated area, that is, at the right side of the vegetated area shown in Fig 1(b).

The eroded case occurs at the faster and deeper part of the channel, which corresponds to the channel upstream, and at the areas of *Phragmites japonica* or *Salix gracilistyla*. On the other hand, the deposited case occurs at the slower part of the channel, which corresponds to the downstream of the channel, and at the areas of *Phragmites communis*, *Miscanthus sacchariflorus* or *Persicaria blumei* [7].

Field survey of the variations of the stream bed inside and outside of the vegetated area was performed, respectively. Fig. 2 shows the variations of the stream bed. Erosion was not occurred seriously inside the vegetated area compared with that outside the vegetated area, which implies that vegetation has functions of erosion relief of the stream bed.

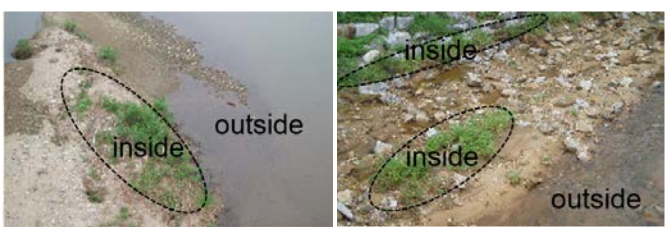
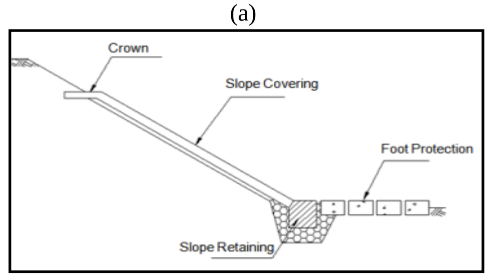


Fig. 2 Variations of stream bed in and outside the vegetated area

If the vegetation will be planted at the toe of embankment slope shown in Fig. 3(a), they will have the same effective functions to mitigate the erosion of the toe as the concrete protection shown in Fig. 3(b). But the concrete protection does not cope with uneven settlement of the toe due to its rigidity, thus it causes the stabilization failure shown in Fig. 4(a). The tetra-pod protection is sometimes installed for protection of the toe shown in Fig. 4(b). On the other hand, the vegetation protection copes with uneven settlement of the toe by its flexibility shown in Fig. 4(c). Moreover, vegetation protection has functions of control of water quality, ecological habitat and amenity compared with that of concrete or tetra-pod. Thus, vegetation protection will be the most efficient method for physical and environmental aspects.

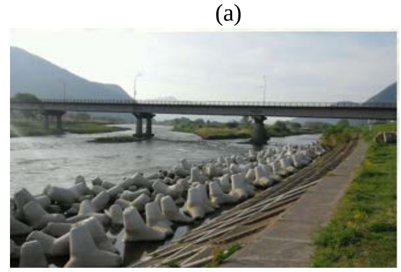
(a)



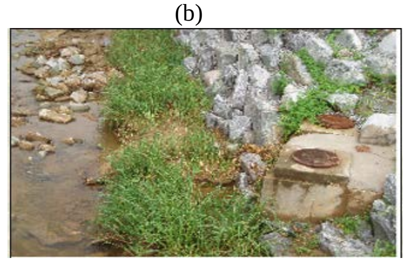
(b)

Fig. 3 Bottom protection using vegetation (a) and concrete (b)

(a)



(b)



(c)

Fig. 4 Bottom protection by concrete; rigid (a), tetra-pod; semi-flexible (b), and vegetation; flexible (c)

III. Field Measurements

Variation of the stream bed was measured by using the reinforced bar staff marked with scales. It was installed inside and outside the vegetated area, respectively and the erosion/deposition could be estimated by measuring the exposed length. Fig. 5 shows the process of marking the scales to the reinforced bar staff.

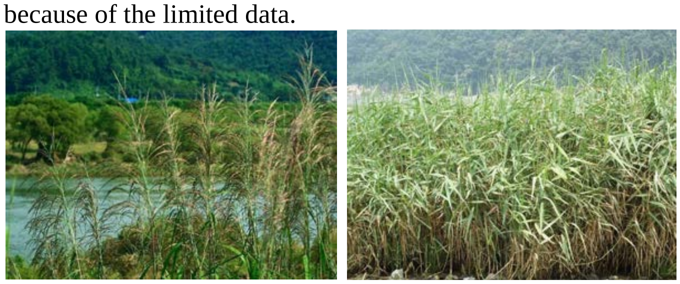
Fig. 5 Process of marking the scales to the reinforced bar staff

Flow velocity was measured by acoustic flow tracker hydrometer which could be detected with ranges 0.01m/s to 3.00m/s. The measuring point of the flow velocity was 60% of the water depth from the river bed (Fig. 6). Flow depth was measured with the scaled steel tape enclosed by plastic pipe (Fig. 7). These values were compared with variation of the stream bed by the species of the aquatic plants.

Fig. 6 Measurement of flow velocity

Fig. 7 Measurement of flow depth

Phragmites japonica, *Phragmites communis*, *Salix gracilistyla* and *Miscanthus sacchariflorus* were chosen as for the typical aquatic plants. They are well inhabited in Korea and have important roles for erosion relief, water control and ecological habitat. They are shown in Fig. 8. Height and density of the plants were measured, but their values were not analyzed because of the limited data.



(a) *Phragmites japonica* (b) *Phragmites communis*

(c) *Salix gracilistyla* (d) *Miscanthus sacchariflorus*

Fig. 8 Typical aquatic plants as *Phragmites japonica* (a), *Phragmites communis* (b), *Salix gracilistyla* (c) *Miscanthus sacchariflorus* (d)

Table1 1 shows some typical results of the variation of stream bed. Here, “height” is the grow height of the aquatic plant, “variation” is erosion or deposition of the stream bed, “-“ means erosion, “+” means deposition, “①” means inside the vegetated area, “②” means outside the vegetated area, and “relief” is erosion relief of the stream bed.

Table 1. Variation of stream bed

Species	Height	Density	Before flood		After flood		Variation		Vegetation role
			①	②	①	②	①	②	
Phraamites japonica	1.5	80	0.45	0.55	0.25	0.75	+0.20	-0.20	deposition
	1.4	70	0.50	0.55	0.40	0.85	+0.10	-0.30	deposition
	1.5	75	0.60	0.45	0.42	0.85	+0.18	-0.40	deposition
	1.0	80	0.45	0.55	0.35	0.75	+0.10	-0.40	deposition
	1.2	70	0.50	0.30	0.70	0.55	-0.20	-0.50	relief
	1.5	75	0.40	0.45	0.75	0.62	-0.35	-0.60	relief
	1.5	80	0.40	0.52	0.80	0.55	-0.40	-0.70	relief
Phraamites communis	1.8	85	0.50	0.55	0.10	0.75	+0.40	-0.20	deposition
	2.4	75	0.60	0.52	0.40	0.72	+0.20	-0.20	deposition
	2.2	80	0.50	0.48	0.40	0.78	+0.10	-0.30	deposition
	2.0	70	0.55	0.55	0.65	0.85	-0.10	-0.30	relief
	2.2	80	0.50	0.50	0.70	0.85	-0.20	-0.35	relief
	1.8	85	0.60	0.45	0.70	0.75	-0.10	-0.30	relief
	1.8	70	0.60	0.52	0.80	0.87	-0.20	-0.35	relief
Salix gracilistyla	1.6	70	0.40	0.56	0.20	0.64	+0.20	-0.08	deposition
	1.8	70	0.55	0.50	0.45	0.90	+0.10	-0.40	deposition
	1.5	80	0.60	0.45	0.40	0.92	+0.20	-0.30	deposition
	1.6	75	0.55	0.40	0.45	0.80	+0.10	-0.40	deposition
	1.5	70	0.55	0.42	0.47	0.82	+0.08	-0.40	deposition
	1.7	75	0.60	0.27	0.70	0.87	-0.10	-0.60	relief
	1.5	80	0.50	0.20	0.70	0.80	-0.20	-0.60	relief
Miscanthus sacchari-florus	0.6	75	0.50	0.55	0.20	0.65	+0.30	-0.10	deposition
	0.4	70	0.55	0.56	0.35	0.66	+0.20	-0.10	deposition
	0.5	65	0.60	0.52	0.50	0.72	+0.10	-0.20	deposition
	0.6	70	0.65	0.55	0.75	0.85	-0.10	-0.30	relief
	0.8	80	0.60	0.52	0.68	0.87	-0.08	-0.35	relief
	0.5	75	0.60	0.45	0.70	0.75	-0.10	-0.30	relief
	0.5	80	0.50	0.56	0.70	0.89	-0.20	-0.33	relief

IV. Results and Discussions

Variation of the stream bed by flow velocity inside and outside the area of *Phragmites japonica* is shown in Fig. 9. Here, "Height" means the elevation height of the stream bed, "-" means erosion, "+" means deposition, "Inside" and "Outside" mean the area inside and outside the vegetation, respectively.

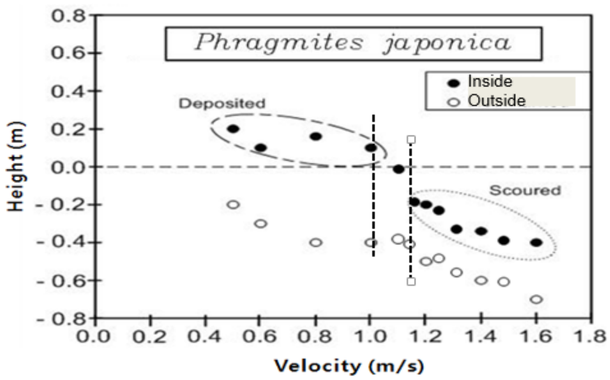


Fig.9 Variation of the stream bed at the area of *Phragmites Japonica*

Phragmites japonica inhabited in the range of more than 1.0m/s of flow velocity except for flow area. Deposition occurred in the range of lower than 1.0m/s of flow velocity, while erosion occurred in the range of higher than 1.1m/s at the vegetated region. But only the erosion occurred outside the vegetated area.

Compared with data of inside and outside of the vegetated area, it can be seen that *Phragmites japonica* has the mitigation function of 0.3m-0.4m of the erosion in the range of higher than 1.0m/s of flow velocity at the vegetated region. This means that *Phragmites japonica* has effective role for protecting the stream bed and for sustaining the stable channel.

Field survey showed that Phragmites japonica inhabits mainly in the range of fast flow and low depth, thus high values of Froude number, which means that it inhabits mainly in the upstream of the stream. Froude number Fr is described by (1).

$$Fr = \frac{U}{\sqrt{gh}} \qquad (1)$$

where U is flow velocity, h is flow depth, g is acceleration of gravity.

Fig. 10 shows the variation of the stream bed inside and outside the area of *Phragmites communis*. Definitions of symbols in Fig. 10 are same as those in Fig. 9.

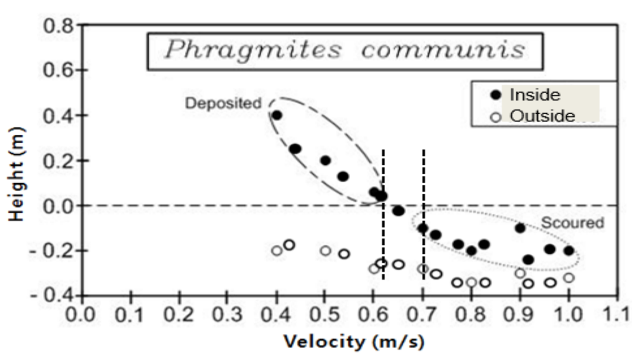


Fig. 10. Variation of the stream bed at the area of *Phragmites communis*.

Compared with *Phragmites japonica*, *Phragmites communis* inhabits in the range of slower and deeper part of the flow area, thus low values of the Froude number, which means the typical case that *Phragmites communis* inhabits the downstream part of the river.

Field survey showed that deposition occurred in the range of lower than 0.6 m/s of flow velocity, while erosion occurred in the range of higher than 0.7 m/s at the vegetated region. But only the erosion occurred outside the vegetated area.

Compared with data of the inside and outside of the vegetated area, it can be seen that *Phragmites communis* has the mitigation function of 0.2 m - 0.3 m of the erosion in the range of higher than 0.7 m/s of flow velocity at the vegetated region. This means that *Phragmites communis* has also effective role for protecting the stream bed.

Fig. 11 shows the variation of the stream bed inside and outside the area of *Salix gracilistyla*.

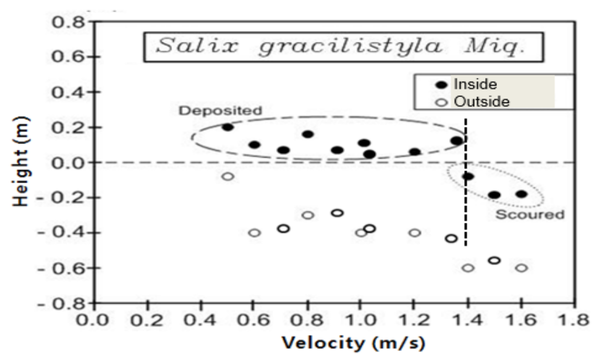


Fig. 11 Variation of the stream bed at the area of *Salix gracilistyla*.

Compared with *Phragmites japonica* and *Phragmites communis, Salix gracilistyla* inhabits in the wide range of flow velocity, which means that it inhabits in the part of the water front as well as of the flow area of the river.

Deposition occurred in the range of lower than 1.2 m/s of flow velocity, while erosion occurred in the range of higher than 1.4 m/s at the vegetated region. But only the erosion occurred outside the vegetated area.

Compared with data of the inside and outside of the vegetated area, it can be seen that *Salix gracilistyla* has the mitigation function of 0.4 m - 0.5 m of the erosion in the range of higher than 1.4 m/s of flow velocity at the vegetated region. This means that *Salix gracilistyla* has greater role to sustain the stable channel than *Phragmites japonica* and *Phragmites communis.*

Variation of the stream bed inside and outside the area of *Miscanthus sacchariflorus* is shown in Fig. 12.

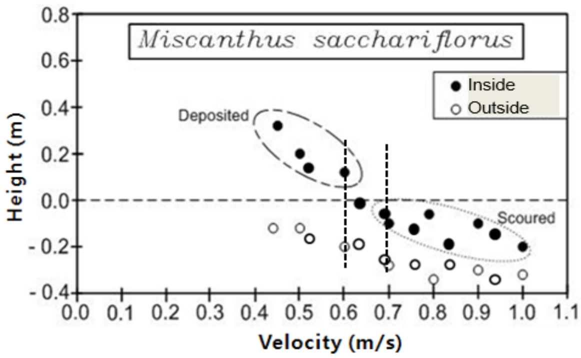


Fig. 12 Variation of the stream bed around the area of *Miscanthus sacchariflorus.*

Miscanthus sacchariflorus inhabits in range of low and shallow flow area, which means that it inhabits the water front or the wetland. [7] Deposition occurred in the range of lower than 0.6 m/s of flow velocity, while erosion occurred in the range of higher than 0.7 m/s at the vegetated region. But only the erosion occurred outside the vegetated area.

Compared with data of the inside and outside of the vegetated area, it can be seen that *Miscanthus sacchariflorus* has the mitigation function of 0.2 m - 0.3 m of the erosion in the range of higher than 0.7 m/s of flow velocity at the vegetated region. This means that *Miscanthus sacchariflorus* has a weaker role compared with that of *Phragmites japonica* and *Salix gracilistyla,* but it has still function of erosion control and has roles for sustaining the stable bed.

From these results, the vegetation has effective roles of erosion relief or deposition of the stream bed.

V. CONCLUSION

Roles of the vegetation to mitigate the erosion of the stream bed or to facilitate the deposition of the fine sediments by the species of the aquatic plants were surveyed by field investigation. The results showed that *Phragmites japonica* inhabits in the range of fast flow and low depth, thus high values of the Froude number. It has function of erosion relief of 0.3m-0.4m in the range of higher than 1.0m/s of flow velocity at the vegetated region. *Phragmites communis* inhabits in the range of slow and deep part of the flow area, thus low values of the Froude number. It has function of erosion relief 0.2m-0.3m in the range of higher than 0.7m/s of flow velocity at the vegetated region. *Salix gracilistyla* inhabits in the wide range of flow velocity, which means that it inhabits in the part of the water front as well as of the flow area of the river. It has function of erosion relief of 0.4m-0.5m higher than 1.4m/s of flow velocity. Thus, it has effective role greater than *Phragmites japonica* and *Phragmites communis* to sustain the stable channel. *Miscanthus sacchariflorus* has a weak role compared with that of *Phragmites japonica* and *Salix gracilistyla,* but it has still function for protecting stream bed. Thus, vegetation has effective roles for erosion relief or for deposition of the stream bed.

ACKNOWLEDGMENT

This research was supported by a grant (12-TI-C02) from Advanced Water Management Research Program funded by Ministry of Land, Infrastructure and Transport of Korean government.

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