Environmental-Friendly Countermeasure for River Bank Scouring: Bio-Engineering as an Alternative Solution

Jaji Abdurrosyid and Anto Budi Listyawan *

Abstract: Scouring and erosion on river bank becomes typical problem on alluvial river. This phenomenon is caused by the movement and scrapping of river flow as helicoidally movement of hydrodynamics' forces comes up. Scouring countermeasure structure on the river bank normally takes an expensive cost, massive project, and does not meet the environmental and esthetics manner. This artificial structure that made of concrete and stone can not meet the Eco-hydraulics spirit and causing an environmental damage. Bio-engineering or Soft-engineering become an alternative solution which more naturally and more friendly to the environment. Bio-engineering is made of porous groynes which is installed at the outer bank. It made of circular bamboo and filled by wattle on the middle the structure. Groynes work like a bag and slow down the river flow on the outer-bank to prevent the erosion. Moreover, this structure acts like a huge bag to trap the sediment that carried by river flood. As a result, the sediment material is accumulated in the groynes and can be used as a media to plant some hydro crop like Ipomea Carnia and Vetiver grass.

Keywords: bio-engineering, eco-hydraulics, river bank, scouring.

I. Introduction

Scouring is defined as the erosion due to flowing water in the alluvial river bed and river slope (Abdurrosyid, 2007). The scour on the river slope is a common problem that can be identified in such plateau region. One of the indications is the appearance of meandering. This erosion will cause severe

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problem for houses and people near the river. Some erosion countermeasures normally are made from an expensive structure, massive and purely hand made from stone, cement, barbed wire, or nylon. Due to high cost of construction, it only installed to protect the important place or in the city where many expensive buildings were built behind the river. While in the rural area, compared to the city with an expensive building, it is almost impossible to build some countermeasures, as the soil has high fertility compared to the city. Many poor people in the rural area feel it is not fair to build countermeasure because their daily life depends on farming near the river.

This fact leads to the innovation of an economical countermeasure which is made from inexpensive and natural materials that fill the hydraulics requirement and considered as environmentally safe. This kind of countermeasure is called Bio-engineering. The current paper is focused on literature study of bio-engineering correlated to the hydraulics analysis of scour countermeasure on the river bank, as a part of eco-hydraulics concept, called environmental hydraulics engineering.

II. Scour Countermeasure on River Slope

The erosion occurs as the river flow gets larger. It will trigger the slope collapse and causes the horizontal and vertical river flow and finally form meandering, braiding. The scour countermeasure will protect the slope from the damage caused by erosion. Normally, a stone or concrete structure is widely used as countermeasure. It is well known that this structure usually expensive and not natural. Moreover it does not meet the spirit of Eco-hydraulics to answer all problems on the holistic ecological and environmental approaches. An Eco-hydraulics slope countermeasure should be built in such conditions by: (1) using a natural material that could be easily collected from nearest region; (2) lower cost of material; (3) taking many employees from local area; (4) providing habitation of water animal and vegetation. Some methods of cheap and natural slope countermeasure have been broadly used in several countries (i.e. Stone rip-rap, wood crib, piles wood parallel with slope, wattle, as illustrated in figure 1).

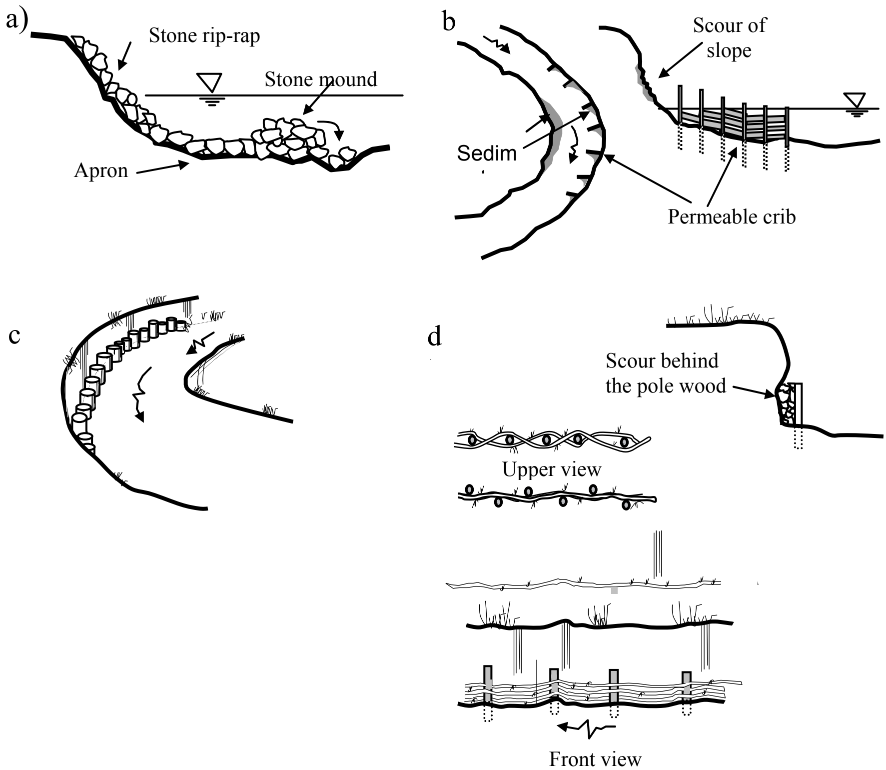


Fig. 1. River slope countermeasure: (a) stone rip-rap, (b) wood crib, (c) pile wood, (d) wattle
(Gordon, N.D., 1994)

III. Scouring and Erosion on River bank

Erosion occurs due to sediment movement in river bed which is triggered by the shear stress that exceeds the critical stress (Graft, 1984). It will cause aggradations and degradation of river bed. If the sediment transportation in downstream balance to the one in upstream, there will be a stable condition. The situation usually reaches in the straight river strip. On the other hand, the meander river, the stable condition is hard to achieve. There is scouring on the concave bank. And the convex bank experience deposition (Annandale, 1987). As the result, the alluvial river strip always changeable and need to be prevented from a large damage to the nearest environment. Originally, the water particle movement followed the strip line. Due to the line strip curve on the river bank, there will be a centrifugal force of water particle, and it will be thrown to the outer-bank, and distort the original line strip (Frijlink, 1968).

The centrifugal force effects the apparent of super elevation of water surface. It will lean and climb to the outer side. As a result, the pressure and the velocity of the water get larger on outer side. The velocity of flow in the bed is slower than the upper side (Joglekar, 1971) due to the super elevation of the transversal velocity distribution. The transversal velocity causes the radial pressure of fluids particle unsteady. The opposite direction of transversal force to the centrifugal force, cause the second force is larger near the surface, and the flow velocity higher (Richardson, 1975). In this concept, there is a resultant force in longitudinal direction (X-axis, see Figure 2). In the transversal direction (Y-axis, see Figure 3), the resultant of the centrifugal and transversal gravity force appear (Frijlink, 1968). The two resultant forces form the total resultant (R_t) which cause the deviation of the water flow, as illustrated in Figure 2. The total resultant triggers the helicoidally flow which is affected by friction on the wall and causes the filament velocity near the centre which is higher than on the wall (Chow, 1965).

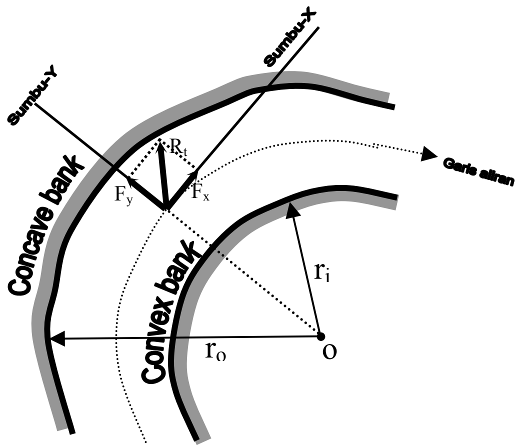


Fig. 2. Forces on the river bank

The helicoidally flow on surface moves faster to the outer side than near the river bed. This is due to the centrifugal force which is larger than the gravity in the transversal net resulting force. As a result, the super elevation comes up and the outer water surface higher than the inner water surface. On the longitudinal resultant force, it can be seen from Figure 3, the upper side is larger than the opposite, although the direction is similar (Joglekar, 1971). Figure 4 shows, on the outer side, water particle will smash the slope surface and causes the erosion and scouring on the outer bank. Due to gravitation, water and sediment particle is moving down and causes a friction and scouring beneath the river. The sediment particle will deposit in the inner bank as the effect of gravity and the slower water flow. Finally, the water moves to the surface and the new helicoidally flow occurs (Joglekar, 1971).

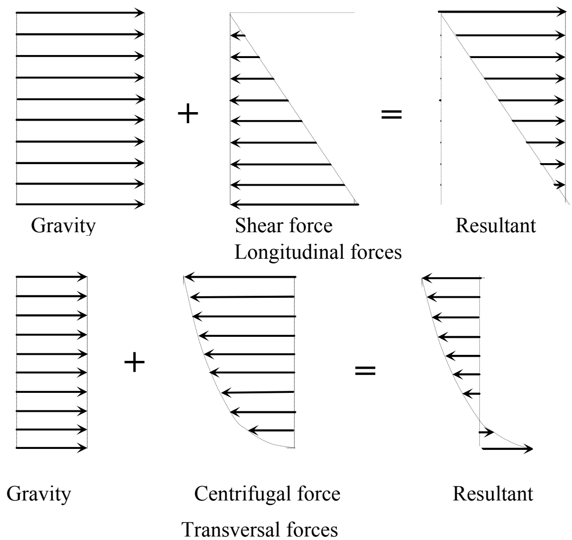
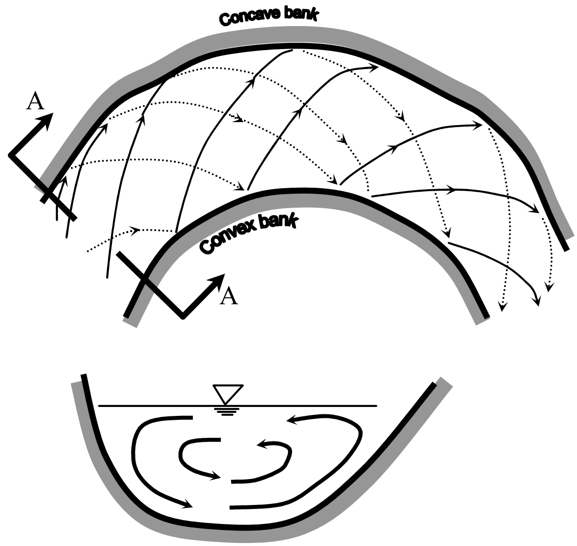


Fig. 3. Resultant forces on river bank



a) Section A - A

Fig. 4. Helicoidally flows on river bank

→ = near surface flow
⋯→ = near bed flow

IV. The Outer bank Protected

Figure 5 shows an assumption of rectangular flow curve. AED is a positive disturbed line and BEC is a negative disturbed line. AEB zone is a deposition area and AEC is scour area (Chow, 1965). The depth scour gets larger from point A to maximum on C, in which the first negative disturbed touch this AC line. The minimum depth scour is attained on inner-bank point D. If AC is assumed by the equation $AC' = b/\tan \beta_1$, hence the central angle θ_o will be:

$$\tan \theta_o = \frac{b}{(r_c + 1/2b)\tan\beta_1} \quad (1)$$

where b = river width, r_c = central jari-jari river bank. And the value of β_1 is

$$\text{Sin } \beta_1 = \frac{1}{Fr}\sqrt{\frac{tanh(2\pi y / b.Cos\beta_1)}{2\pi y / b.Cos\beta_1}} \tag{2}$$

where y = flow depth on river bank, Fr = froude number,

$$Fr = \frac{V}{\sqrt{gy}} \tag{3}$$

The maximum scouring is in interval of 2 θ_o on outer-bank, and the maximum deposition is similar to the inner-bank. According to Harison (in Chow, 1965), a fine result will come up in the trapezoidal curve application design by the value of Fr = 1.6. The outer-bank length that is protected from scouring from one disturbance (interval 2 θ_o) is

$$L = \Delta\, \theta_o\, r_c$$

$$= 2\, \theta_o\, r_c \tag{4}$$

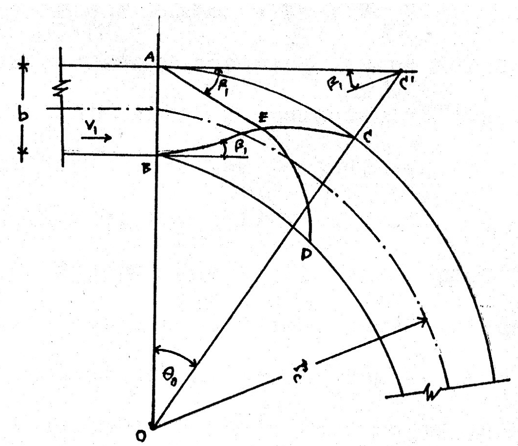


Fig. 5. Disturbed region

V. Bio-engineering

Bio-engineering that commonly called soft-engineering is the scouring protection effort by using the combination of bamboo, Vetiver and Ipomea Carnia (SMEC, 1997). Vativer grass can grow in various degree of soil fertility; can live in a dry or wet condition, easy and simple to plant. The root moves down the earth more than 3m depth. It is classified as long term vegetation. Its leaf is growing fast that very beneficial in countering the erosion due to the water rain. The strong root retains the soil and the nearest structure (SMEC, 1997). Currently, the Vetiver is widely used in countering the erosion around the world. Ipomea Carnia is a water vegetation and easily to plant. Its root is very strong and moves down the earth. It can be planted on the sediment deposit in inner bank (SMEC, 1997). Bio-engineering can be developed in such condition: (1) the flood water velocity is less than 1.5 m/sec; (2) the water flow brings suspended sediment; (3) the river bed is made off non gravel soil. An example location that succeeds in developing bio-engineering is Cisanggarung River on the downstream of Tawangsari Rubber Dam (FTP UGM, 1998). Figure 6 shows the bio-engineering design made from vertical bamboo on river bank which potentially scoured. The bamboo is arranged vertically and horizontally and mixed with some compacted wattle and form a porous crib. It will counter flood flow, retain the river slope and deposited the sediment in the slope toe. As the sediment deposit formed, Ipomea Carnia is begun to be planted (Figure 7), and will make the deposition faster. Obviously, when the Ipomea Carnia gets stable, it will replace the old structure of bamboo to counter the water flow and retain the river slope effectively.

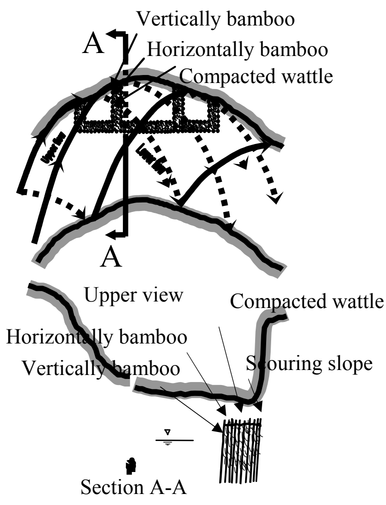


Fig. 6. Bio-engineering for protecting river bank scour (Porous crib)

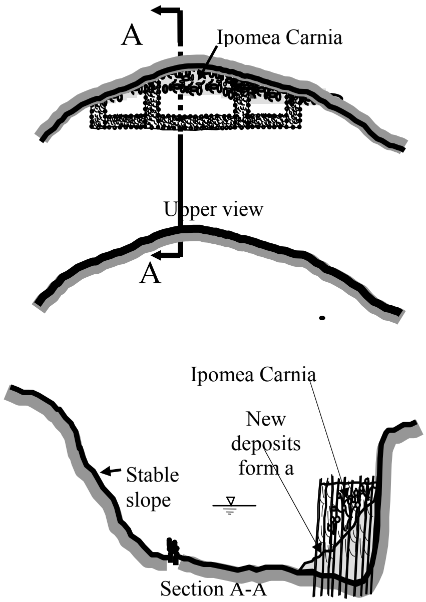


Fig. 7. Bio-engineering for protecting the river bank scour (Ipomea Carnia or Vetiver planting on a new deposit)

VI. Summary and Conclusion

1. The old method of erosion countermeasure was a high cost structure, massive and unnatural. It is in contrary with the spirit of Eco-hydraulics which adopts an ecological and environmental approach.
2. Bio-engineering is an erosion countermeasure that meets the eco-hydraulics concept. It is made from the combination of bamboo, Vetiver grass, and Ipomea Carnia.
3. The scouring of river bank can be protected by installing bio-engineering that acts to minimize the helicoidally water flow since the roots of Vetiver grass

and Ipomea Carnia have a massive strength to counter the very high flow velocity and deposit the sediment for river slope conservation.

4. For one disturbance, the maximum scour is in the interval of 2 θ_o on both outer and inner slope.

VII. Acknowledgment

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IX. Biographies

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