GROYNE TO PREVENT RIVERBANK EROSION ON MEKONG RIVER

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Riverbank erosion is one of major problems in land management in the lower Mekong River basin. In the case of Laos, a series of groynes was installed in 1998 to prevent riverbank erosion at Ban Tonpeung, Bokeo Province. The groyne project had a concept to break an erosion cycle caused by monsoon fluctuation using nature river features. The groynes, consist of rock riprap, were designed to attract deposition on the bank foot in high-water seasons, which would work as counterweight against circular slips in low-water seasons. In total, 20 structures had been built by 2004 and monitored in 2010. The groynes were working successively to make the riverbank stable, create a nature-friendly waterfront and improve water access for residents. This paper presents cause analysis of the erosion, design specifications of the groynes and evaluation after construction, with recommendations for riverbank management in monsoon regions.

Key Words : *Groyne, Fluctuation, Riverbank Erosion, Circular Slip, Sediment*

1. INTRODUCTION

Riverbank erosion is one of the most serious problems for land management in developing country in Asia. Its monsoon climate, which brings clear division of rainy and dry season, provokes significant fluctuation to cause eventually large-scale erosions. To prevent them, in some cases, foreign donors may support developing country to construct some river facilities; however, the government’s budget for facility maintenance is always insufficient.

In such general condition, Lao government had been suffered from 3km-long Mekong riverbank erosion in Bokeo province. By request from Lao government, the author installed a unique facility on Mekong in 1998 applying Japanese traditional river engineering. It was a series of groynes, which aimed to attract deposition to cut a progressing erosion circle. After construction of 20 groynes by 2004, they worked well and their impacts to make the river bank stable, nature-friendly and easy-to-use for residents were confirmed by the author in 2010. Lao government, understanding their effectiveness and cost performance, has been introducing this technique to other erosion sites up to now.

This paper presents the groyne project on Mekong focusing on cause analysis of the erosion cycle and design specification selectable under restrictions of available material, technical capability and local budget. Its construction process and verified functions shows us advantages of groyne on monsoon rivers and recommendations for international cooperation for river management.

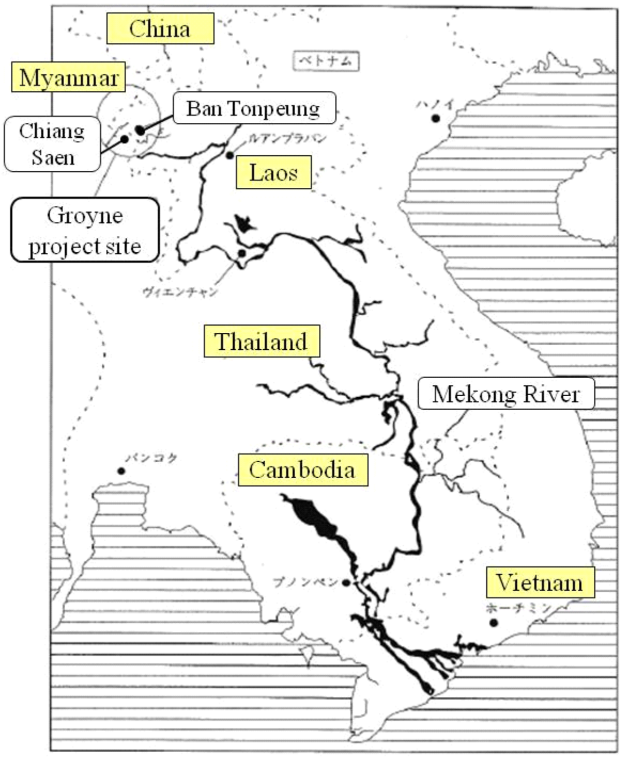

Fig.1 Mekong river and groyne project site

2. FIELD SURVEY

The Mekong River is one of the largest rivers in Southeast Asia, measuring 4,880 km in the main channel and 795,000 km^2 in the river basin (**Fig.1**). The hydraulic characteristics are affected by typical monsoon precipitation. The discharge in the lower Mekong is sustained by snow melt in Tibet plateau and enriched by widespread rainfalls from May to October[1)]. Because more than 80 percent of the annual rainfall comes in the rainy season, the mean monthly discharge at the Chiang Saen observation station in August is almost eight times greater than that in March[2)]. The dynamism provides an annual water-level fluctuation of nearly 10 meters. And the largest flood recorded 16,000 m^3/s in 1966[3)].

The eroded riverbank erosion at Ban Tonpeung, Bokeo Province, Laos was opposite of Ciang Saen, Thailand. Lao government had a plan to open an international river port at this village, however, the riverbank was reported to retreat 20 meter in 20 years. The erosion became the top-priority problem to be solved.

The author surveyed the site in November 1997 and February 1998 to and found facts as follows.

(1) Riverbank erosion

The erosion site was on outer bank Mekong meandering, which has 1/2,500 longitudinal slope and 400 meters width with a wide point-bar on the inner side[4)]. Flow velocity in high-water season was 3 m/s in the central part and 1 m/s at the bank side.

The eroded bank kept a sheer cliff of about 10 m heights with no vegetation due to half-year submergence and soil displacement (**Photo 1**).

The cliff consisted of diluvial layers and had deeply laterized. On mudstone section, non-disturbed bedrock was not solid in wet condition enough to be scooped by a finger (**Photo 2**). Cobble section on upstream part was covered by 10cm diameter materials (**Photo 3**), which had come out of the diluvial layer because the Mekong tractive force could not force them to move. The opposite point bar of 0.1 mm fine sand covered a half of the cross section of Mekong.

(2) River facilities and engineering materials

While concrete/riprap revetments protected Ciang Saen town area, Lao side had no hard structure. Only at a boat stop, the riverbank slope had temporally pile-and-sandbag protection, allowing ground soil to be sucked off by vessel waves.

Although availability of engineering materials is a decisive factor for river works, it was difficult to find useful material around the village. There were no steel, cement or rock. Houses had timber structure, but logging was prohibited under an anti-deforestation policy.

As a result of investigation trips, a triangular hill was discovered in 10 km north form the village (**Photo 4**). It was an outcrop of less weathered granite with 2.8 in the density. The rock was minable and transportable by local workers who had experience of road construction.

(3) Comments of residents

Local residents testified that a half of village had been eroded and waterfront was necessary for their transport, fishery, laundry and bathing. Among them,

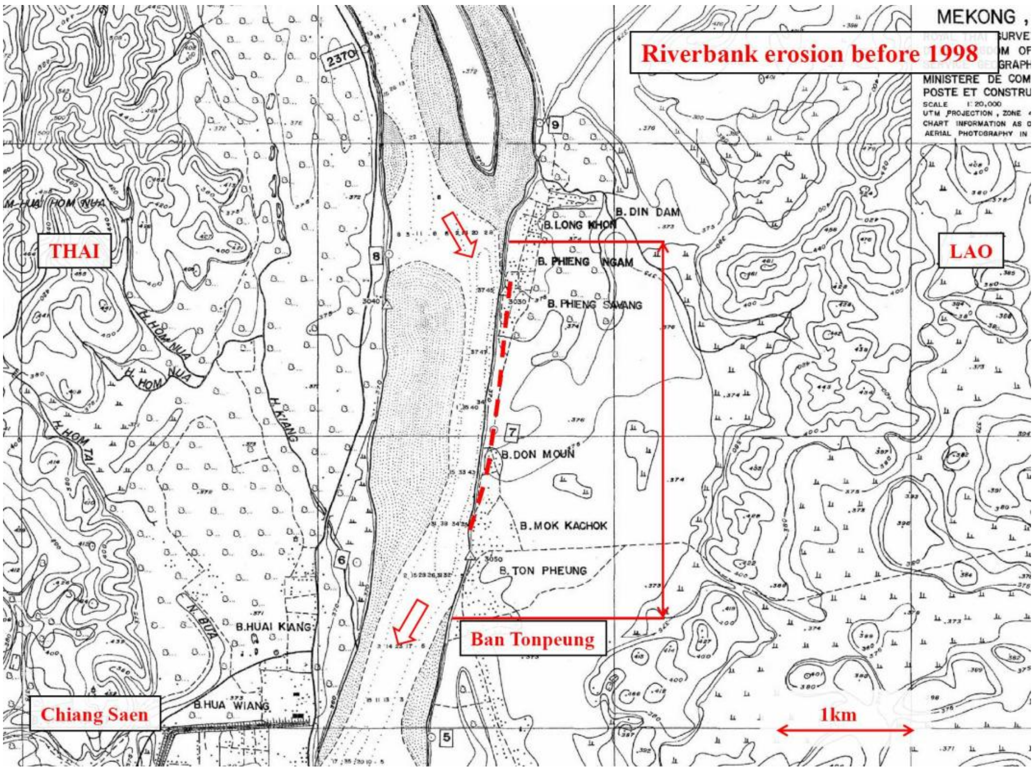

Fig.2 Erosion site in Boko province, Laos

there were 3 worthy comments.

- Mekong overflowed in 1966, but the village was rarely inundated.
- Erosion occurred in a couple of years, not every year.
- Regardless of water level, residents put a path on the cliff because of water access.

Photo 1 3km-long riverbank erosion (February 1998)

Photo 2 Laterized muddy rock (February 1998)

Photo 7 Cobbles on the eroded riverbank (February 1998)

Photo 8 Small triangular hill of granite (February 1998)

3. CAUSE ANALYSIS

The findings indicated that the progressive erosion was triggered by circular slip which has around 5-year return period. Then the author made a hypothesis of a cyclic erosion illustrated in **Fig.4**. This could be explained as a compound effect of the diluvial bank strata and dynamic fluctuation.

a) Cliff formation under the water

At a concave bank of a river meandering, tractive force of a spiral flow works on both riverbank and riverbed. Especially in high-water seasons, stronger sweeping stress removes smaller particles away leaving larger materials and undisturbed diluvial layers. Yearly repeating fluctuation of Mekong results in the formation of a 10m sheer cliff under the water.

b) Cliff emergence and circular slip

The cliff will emerge in the next low-water season. The open-air cliff is stable and dried up due to arid climate. In coming of the next rainy season, a heavy rain on the top of the bank is able to upset the gravity balance to cause a circular slip. Then the bank retreats approximately 5 meters. The collapsed soil clump accumulates at the foot of the cliff to stabilize the remaining bank.

c) Collapsed soil to be swept away

When the river rises again in high-water seasons, the collapsed soil clumps are submerged with less solidity. That will be easily swept away little by little. The tractive force will reform a 10m cliff at 5m set-back position in approximately 5 years.

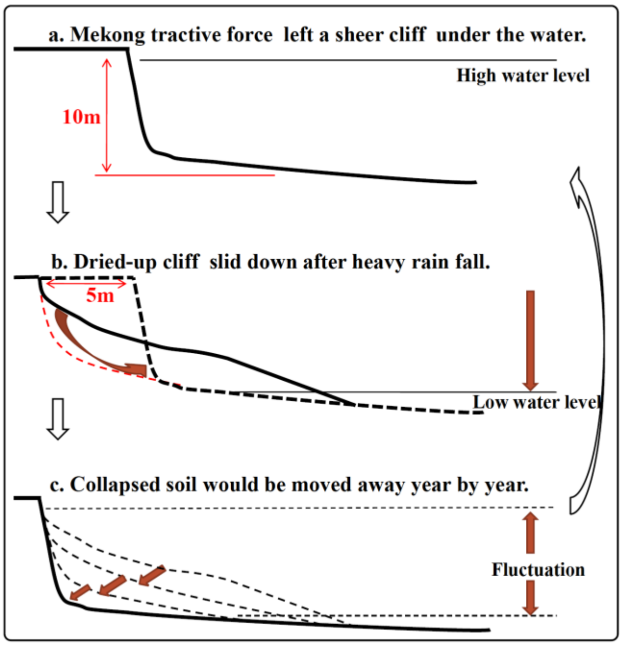

Fig. 3 Cyclic erosion in monsoon fluctuation

4. DESIGN SPECIFICATION

As countermeasures against the cyclic erosion, the author and Lao engineers compared 3 types of solution: gabion revetment, ballast counterweight and groyne for deposition.

+ Gabion revetment

A direct protection to cover the surface of the sheer cliff using gabion baskets could be a solution, when construction budget could be prepared. In Laos wire and geotexstiles had to be imported, so that the method installed in Vientiane had cost 1,530 USD/m. Foreign exchange shortage was quite difficult to overcome.

+ Ballast counterweight

Counterweight was a common-sense approach to prevent circular slips. Cobble material was available in Lao territory and transportable using vessels in high-water seasons. However, local technical capacity was not enough to ensure work quality under invisible water and it had to take a long period of time to cover the whole eroded site.

+ Groyne for sediment

Groyne had a function to attract deposition which might break the erosion cycle. Masonry riprap bases were not difficult to construct and natural willow could grow up on it. Such permeable groynes were expected to reduce flow velocity in front of the eroded bank, however, there was no precedent to judge its effectiveness and its cost.

Through a comparison of available material, technical capability and local budget, Lao government selected the groyne project. The author drew up a blueprint of a series of permeable groynes, referring Japanese traditional river engineering, in which groyne was used to reflect/attract main flow[6]. Each groyne was designed to have a masonry base (**Fig. 4**) and open space on it for vegetation. Lao government finally made decision to build a couple of groynes to test practical effects and actual cost.

- Rock size: over 20 cm diameter

Referring an empirically-derived formula[6] to keep still in 3.0 m/s flow. Same with existing concrete blocks and 4 times larger than riverbed gravels.

- Length: 40 m

For dry-work workability in the low water season. Equivalent to one-tenth of the river width.

- Height: 6m

Half of the cliff heights to be submerged during the high water season.

- Crest width: 3m

To plant willows on clogged masonries.

- Slope: 1:3 and 1:1.5

Imitation of stable natural riverbank of 1:3 for the head/downstream side. Half of it for the upper.

- Interspace: 100 m

2.5 times longer than the masonry to cover the 3km early. Predetermining an additional short groyne for another collapse in the interspace.

- Work sequence: downstream first

To prevent scouring due to diffraction flow.

- Inspection and rehabilitation: every year

To repair quickly for smaller damage.

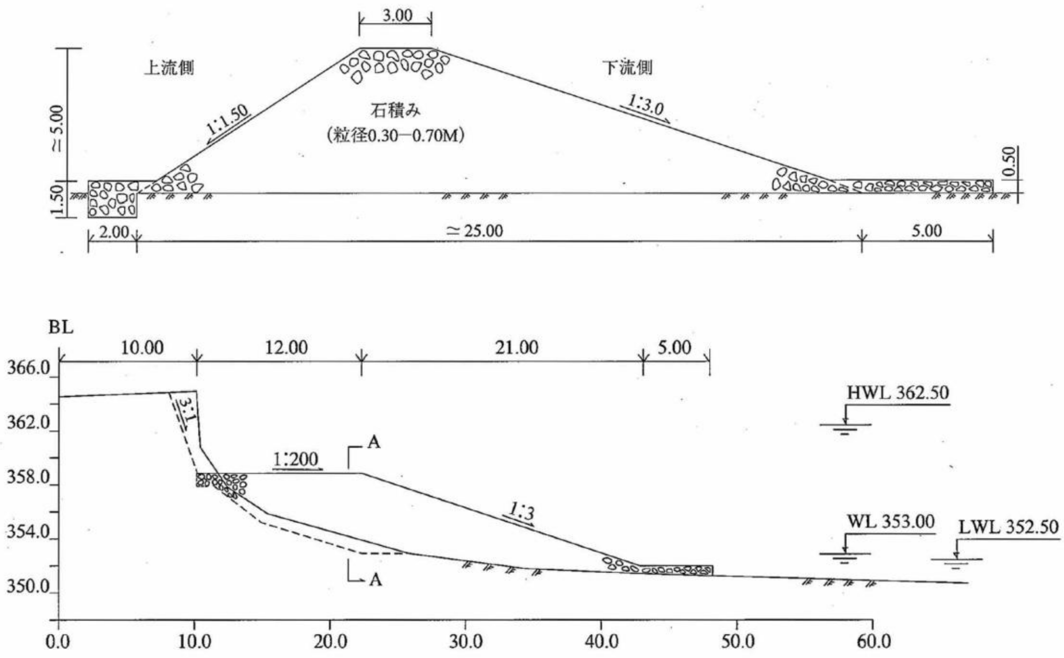

Fig.4 Side view and cross-section of standard masonry groyne

5. CONSTRUCTION PROCESS

Lao government got started the test construction in February 1998. The first masonry was set at 200m point from the boat stop. During the low water season, 30-70cm diameter granite transported from the hill quarry were laid out in a circle and piled up to make a 6m-high impermeable base by backhoes and workers (**Fig. 5**).

4 masonry had been constructed in 3 low water seasons by April 2000 to find following facts at the time (**Fig. 6**):

- no sinkage of rock materials and no deformation on the masonry during 2 high water seasons
- initial deposition between masonries
- willow rooting on the masonry No. 2 by itself
- 2 months construction period for 1 masonry
- 30,900 USD for 1 masonry, equal to 309 USD to cover 1m riverbank at an average cost

Photo 5 No.1 and 2 masonry under construction (May 1998)

Photo 6 No.1, 2, 3 and 4 masonry completed (April 2000)

Photo 7 Masonries and deposition (January 2002)

Lao government was satisfied by the results and decided officially to continue the groyne project and since then Lao engineers constructed 2-4 masonries every year (**Fig. 7**).

In 2004, No. 19 and 20 masonry were built near the boat stop to finish the works including no human-induced willow planting. Then the groyne project at Ban Tonpeung was terminated. The reason was that the most dangerous 2km section was covered by the groynes and deposition and remaining 1km was relatively stable owing to waterside cobbles. Lao government, actually, could reallocate the limited budget to other riverbank erosion site with urgency.

6. EVALUATION

After the groyne project, Ban Tonpeung were inundated twice by bank-full floods in 2002 and 2008[7]. The masonries were submerged completely and provided opportunities to accelerate deposition. The situation in February 2010 could be checked in the satellite image (**Fig. 5**).

In June 2010, the author conducted a site inspection to confirm that the masonries with natural vegetation to be a series of permeable groynes had worked out to make the riverbank stable in 12 years. It could be evaluated that the groynes succeeded in not only cutting the erosion cycle but also making up nature-friendly environment and easy-to-use waterfront.

+ Groynes and riverbank

On the 20 masonries, little deformation was found and natural vegetation had been growing. No. 1 masonry, especially, was entirely veiled by green trees. The masonry was fixed by their roots and functioned as a concealed resistance (**Photo 8**). Calm water zone was created between No. 2 and

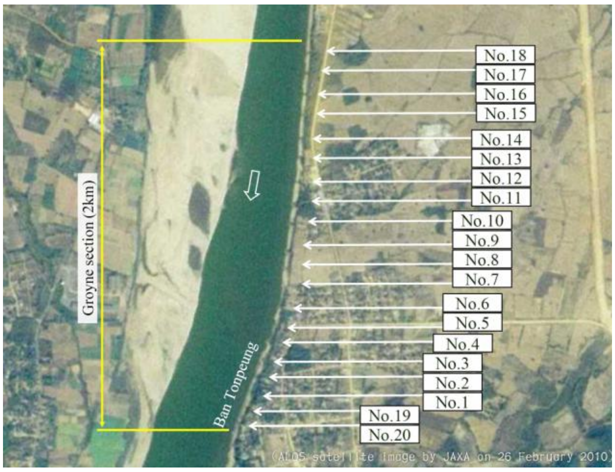

Fig. 5 Work sequence of 20 groynes
(ALOS satellite image by JAXA on 26 February 2010)

No. 3. In this section, a thick sand sediment up to the masonry's crest level shaped a simple arc (**Photo 9)**. A young willow had just taken root on No. 11 and would invite other vegetation to make the groyne stronger (**Photo 10)**.

+ Construction cost

According to Lao government, the 20 masonries, constructed in 1998-2004, had cost 237 USD/m. It is a result of Lao engineers who always tried to arrange the design for cost-cutting. The cost is affordable for Lao government to spread out the groyne technique all over Laos.

+ Social acceptance

Q&A also showed favorite appreciation of residents such as: high quality, low price, helpful to stop erosion, and a lot of fish and plants living around the groynes.

Photo 8 No. 1 groyne concealed by vegetation (June 2010)

Photo 9 Calm water between No. 2-3 groynes (June 2010)

Photo 10 Mekong willow on No. 11 groyne (June 2010)

7. CONCLUSION

To conclude this report, the author can withdraw 3 notable recommendations for international technical cooperation using Japanese traditional river engineering from the Mekong groyne project.

(1) Field-oriented approach

The most precious recommendation is to consider countermeasures on the site. At a less-informational river, in particular, site analysis must be essential. Then it is able to design proper measures under restrictions of available material, technical capability and local budget. Also, maintenance must be taken into consideration in the design stage.

(2) Nature-interactive engineering

How to use features of Mekong was the key concept of the groyne project. River-made deposition and vegetation has been making the riverbank more and more preferable. In such a case, step-by-step procedure is useful to confirm and predict time-dependent reactions. The effect will appear gradually, not just behind constriction works.

(3) Capacity development of river engineers

Capacity development of river engineers is necessary. Mekong groyne's result is mainly accomplished by Lao engineers who understood and pursued the project adjusting the design to Lao social/natural conditions. A capable engineer can do a good job using mostly qualitative assessment with little quantitative information.

Above 3 points are also important for river management in Japan. In specific, dotted groynes have more potential for economical advantage and ecologic upgrading than sheeted revetment. Groyne technique shall be developed.

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