GROYNE TO PREVENT RIVERBANK EROSION ON MEKONG RIVER

Hirotada MATSUKI, Dr.Eng.
Ministry of Land, Infrastructure, Transport and Tourism (JICA Expert 1997-2000 for Laos/2013- for Vietnam)

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 since 1998 to protect riverbank 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 masonry and vegetation, were designed to attract deposition on the bank foot in high-water seasons, which would work as counterweight against slip failures in low-water seasons. In total, 20 structures had been built by 2004 and verified in 2014. The groynes were working successively to make the riverbank stable, create a nature-friendly waterfront and improve water access for people. This paper presents cause analysis of the erosion, design parameters of the masonry and evaluation over 10 years 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 especially in developing countries in Asia. Its monsoon climate clearly divides rainy and dry season, resulting in significant water fluctuation to cause eventually large-scale erosions. To prevent them, the governments or foreign donors had built some riverbank protections, however, the facilities brought other problems in some cases and the maintenance cost is not sufficient in most cases.

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 designed 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 had been working well to make the river bank stable, nature-friendly and easy-to-use for people, which were confirmed by the author in 2014. Today Lao engineers, who understand effectiveness and cost performance of groynes, have been re-designing and applying to other erosion sites.

This paper reports inputs of the Mekong groyne project focusing on cause analysis of the erosion cycle and design parameters selectable under strict conditions of material, workmanship and budget. Then outcomes indicate us both advantages of groyne on monsoonal rivers and recommendations for international cooperation in river engineering.

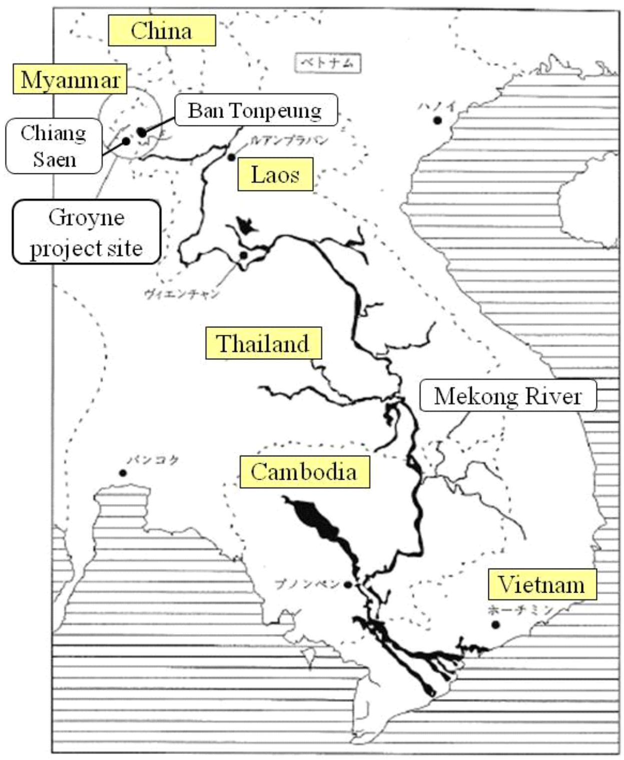

Fig.1 Mekong river and groyne project site

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 monsoonal 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 rain falls in the rainy season, the mean monthly discharge in August is almost eight times greater than that in March at the Chiang Saen observation station[2)]. The largest record was 16,000 m^3/s in 1966[3)] and the dynamism produces an annual water-level fluctuation of nearly 10 meters.

At the opposite of the Chiang Saen, riverbank of Ban Tonpeung, Bokeo Province, Laos had been eroded severely (**Fig.2**). Lao government had a plan to open an international river port at the village, however, the riverbank was reported to step back 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 find facts as follows.

(1) Riverbank erosion

The erosion site was on outer bank of a Mekong bend, 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 of laterite soil. On mudstone section, non-disturbed bedrock was not solid in wet condition enough to be scooped by a finger (**Photo 2**). Upriver cobble section was covered by 10cm diameter materials (**Photo 3**), which had come out of the diluvial layer because the tractive force is not strong to carry them form upstream. The opposite point bar of 0.1 mm fine sand covered a half of the cross section.

(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. Steel, cement or rock was not there. Timber was used for housing but logging was prohibited under an anti-deforestation policy.

As a result of searching 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 people stated that a half of village had been eroded and waterfront was necessary for their transport, fishery, laundry and bathing. Among them,

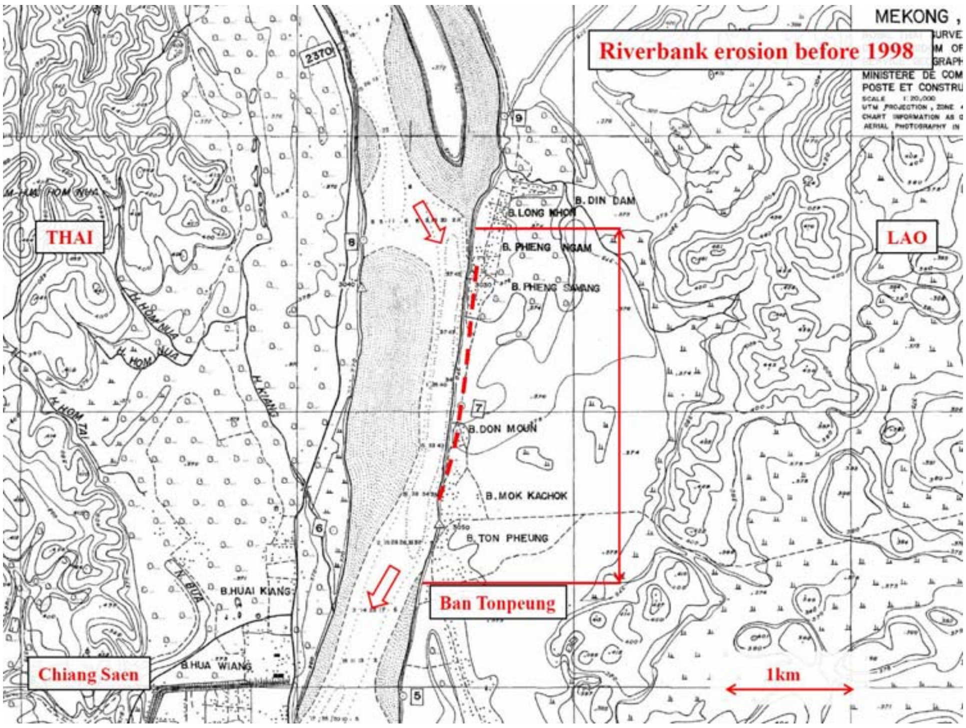

Fig.2 Erosion site in Boko province, Laos

there were 3 worthy comments.

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

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

Photo 2 Laterized muddy rock (February 1998)

Photo 3 Cobbles on the eroded riverbank (February 1998)

Photo 4 Small triangular hill of granite (February 1998)

3. CAUSE ANALYSIS

The findings indicated that the progressive erosion was triggered by slip failure repeating with some return period of a couple of years. Then the author made a hypothesis of a cyclic erosion as illustrated in **Fig.3**. This could be explained as an interactive effect of the diluvial strata and dynamic fluctuation repeating the process a), b) and c).

a) Cliff formation under the water

At a concave bank of a river bend, spiraling flow washes both riverbank and riverbed. Especially in deep water of 10 meters, strong shear force removes small particles away. After repeating high-water seasons, Mekong River finally leaves a sheer 10-meter cliff of undisturbed diluvial layers under the water.

b) Cliff emergence and slip failure

In the next low-water season, arid air dries up the cliff which keeps stability with its cohesion. In the end of the season, however, first heavy rain seeps into the cliff top and upsets the gravity balance to suddenly cause slip failures. The bank edge line steps back approximately 5 meters and collapsed bulk soil regain stability of the bank.

c) Collapsed soil to be swept away

The bulk soil undergoes dry and wet conditions. Clumps of soil became smaller in low-water seasons and soil particles are swept away in high-water seasons. All of them are entrained little by little. After a couple of years, a 10-meter cliff will stand again at 5-meter set-back position.

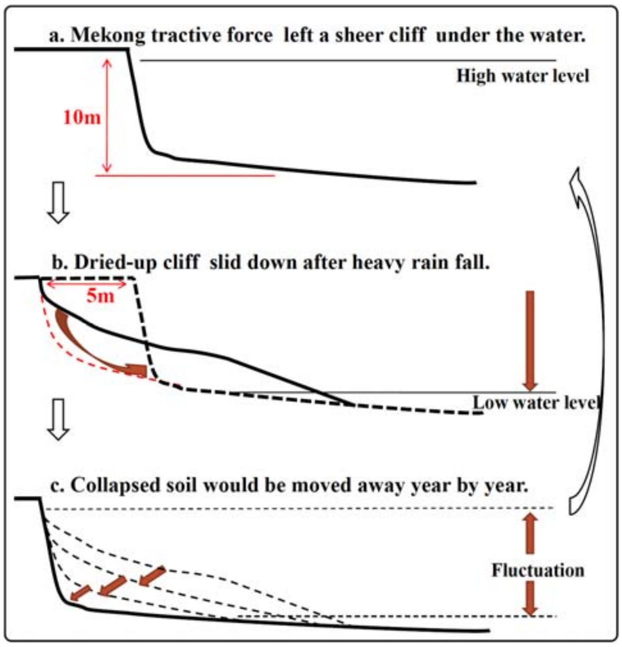

Fig. 3 Cyclic erosion in monsoonal fluctuation

4. DESIGN PARAMETERS

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

Option 1 - Gabion revetment

Revetment made of gabion boxes is a direct protection of the sheer cliff and Lao engineers had experience it around Vientiane. The work cost 1,530 USD/m because metal wire and geotexstile had to be imported. The budget is not sufficient, moreover the previous works was deformed by local scours and required budget for rehabilitation.

Option 2 - Ballast counterweight

Counterweight is a common-sense approach to prevent circular slips. Cobble material was available within Lao and transportable using vessels in high-water seasons. However, work quality cannot be ensured under invisible water and the 3-km length needs a long period of time to cover the whole site.

Option 3 - Groyne for sediment

Groyne is an indirect protection but able to attract deposition instead of human-induced works. For this purpose, permeable groynes are necessary to reduce velocity of flow, then, rock material can form masonries as a base of willow trees. However, there was no precedent to judge its effectiveness and its cost.

Through a comparison of available material, technical capability and local budget, The groyne project was selected. The author drew up a blueprint of a series of permeable groynes referring Japanese traditional river engineering, in which groyne was used to block or retard main flow[6].

Original design has a masonry base (**Fig.4**) and open space for vegetation with parameters as:

- **Rock size: over 20 cm diameter**
  Referring an empirically-derived formula[6] to keep still in 3.0 m/s flow. Same with minimum concrete blocks on the bed and 4 times larger than maximum gravels transported by Mekong.
- **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 not to block high-water flow.
- **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.
- **Spacing: 100 m**
  2.5 times longer than the masonry to cover the 3km early. Predetermining an additional short masonry at another collapse between groynes.
- **Work sequence: downstream first**
  To prevent scouring due to diffracted flow.
- **Patrol and repair: every year**
  To find small damages to repair them soon.

Lao government made decision to build a couple of them to test practical effects and actual cost.

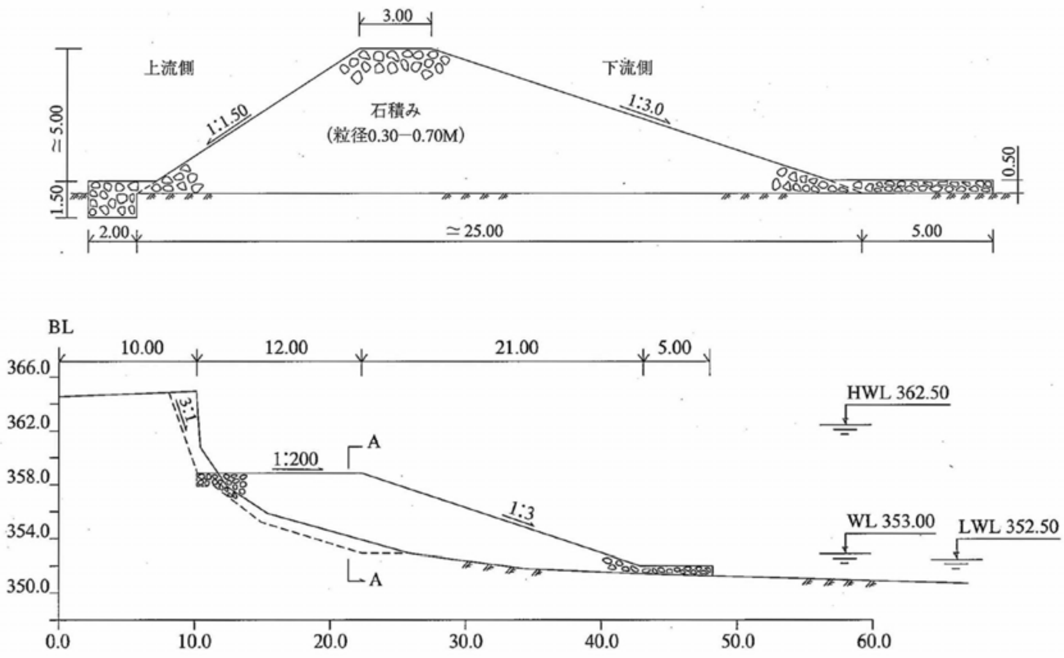

Fig.4 Cross-section and side view of masonry groyne

5. CONSTRUCTION PROCESS

Lao government 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 (**Photo 5**).

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

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

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)

The result was acceptable for Lao government so that they determined to continue the groyne project. Since that, Lao engineers constructed 2-4 masonries in every low-water season (**Photo 7**) and finally 20 in 7 years. The situation in February 2010 could be checked in the satellite image (**Photo 8**).

In 2004, No. 19 and 20 masonry were built near the boat stop to finish the works excepting 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 deposition between groynes and remaining 1km was relatively stable owing to waterside cobbles. Lao government, actually, shifted the limited budget to other riverbank erosion sites in urgent.

6. EVALUATION

After the groyne project, Ban Tonpeung area was inundated by bank-full floods twice in 2002 and 2008[7]. The masonries were submerged completely and provided opportunities to get deposition for vegetation.

In February 2014, the author observed the site and confirmed that the masonries with natural vegetation had become a series of permeable groynes to stop erosion completely. 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.

(1) 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 resistance of the bank (**Photo 9**). Slackwater area was created in each spacing. Thick sandy sediment covered the bank up to the

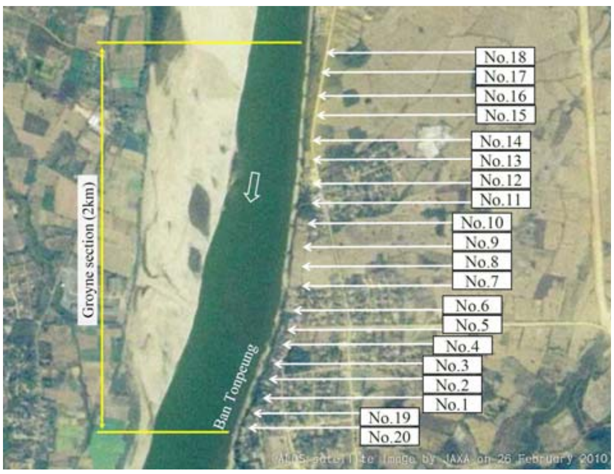

Photo 8 Work sequence of 20 groynes
(ALOS satellite image by JAXA on 26 February 2010)

masonry's crest level and shaped a simple arc of waterline. The sediment was used in daily life of people and tips of masonries were a jetty of river boats (**Photo 10 and 11)**.

(2) Construction cost

According to Lao government, the 20 masonries, constructed in 1998-2004, cost 237 USD/m. This significant cost saving was a result of creative efforts of Lao engineers who changed design parameters. Groyne techniques were applied to other sites all over Laos.

(3) People's acceptance

Q&A conducted in 2010 also showed favorite appreciation of people and engineers. They commented that the groynes stopped erosion by high quality with low price and a lot of fish and plants living around the bank.

Photo 9 No. 1 groyne concealed by vegetation (February 2014)

Photo 10 Deposition between No. 6-7 groynes (February 2014)

Photo 11 Riverbank protected by groynes (February 2014)

7. CONCLUSION

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

(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 rivers was the key concept of the groyne project. River-made deposition and natural vegetation has been making the riverbank better. In such a case, step-by-step or no-regret procedure is useful to confirm and predict time-dependent reactions. The effect will appear gradually, not just behind constriction works.

(3) Capacity of river engineers

Capacity of river engineers is absolutely necessary. Results of the groyne project were achieved by Lao engineers who had driven the project gaining experience. And they could apply the technique to other projects. Experienced engineers can do good job using mostly qualitative assessment with little quantitative information.

Lastly the author points out advantage of groyne. Stand-alone structures have potential to upgrade riverbank both economically and ecologically as compared with continuous revetments. Groyne technique shall be studied and developed.

REFERENCES

1) CREST Asian River Basin Water Policy Study Team : Mekong River Basin, pp. II20, II37, Japan Science and Technology Agency, 2009.
2) Overview of the Hydrology of Mekong Basin, pp. 32, Mekong River Commission, 2005.
3) http://www.mrcmekong.org/programmes/wup/Monitor-stations/Chiang-saen.htm.
4) Hydrographic Atlas Mekong River Volume I (km 2373-km 2286), pp. 2-002, Lao PDR and Thailand, 1996.
5) Tan-emon KOBAYASHI, River Management (Japan Old Agriculture Collection 65, pp.5-44, 1997.
6) Technical Transfer Report on Riverbank Protection Technique, pp. 24-25, IDI-Japan, 2005.
7) Annul Mekong Flood Report 2008, pp. 44, Mekong River Commission, 2009.