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Mainstreaming Slope Stability Management – Hazard and Risk Assessment – to Laos Practitioners

Theme 2

Factors Influencing Slope Stability in Laos

2.3 – River & Stream Erosion

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River Bank Erosion

The factors controlling river bank erosion include:

- **The rate and amount of sediment supply**
- **The rate and amount of water supply**
- **The geology of the catchment area**
- **Vegetation cover and land use in the catchment area**

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Effects of River Bank Erosion

River bank erosion has two main outcomes:

- **Bank Scour**

  the direct removal of bank materials by the physical action of flowing water

- **Mass Failure**

  bank collapse and slumping which occurs as a single event

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Stream Types and Characteristics
Mountainous & Hilly Streams

General type of country or slopes	Type of stream or crossing	Typical Materials exposed in channel	Dominant channel processes	Possible hydraulic problems
Mountainous; streams with steep slopes	Boulder torrent	Bedrocks and boulders	Pools and rapids; waterfalls	Bank erosion; blockage by debris
	Braided gravel river or outwash valley train (also occurs outside mountains)	Sand, gravel, cobbles	Transport of coarse alluvium; erratic shifting of main channels	Change in location of erosion as channels migrate during times of flood
	Alluvial fan	Sand, gravel, cobbles	Deposition of coarse alluvium; sudden shifting of channel	Change in location of erosion, channel realignment, scour
Hilly; streams with moderate slopes	Entrenched river (also in mountains)	Bedrock, shale, etc.	Minor bank erosion: transport of thin veneer of alluvium	Few problems compared to other types; possible blockage by debris
	Wandering river	Sand, gravel, cobbles	Valley widening by erosion of valley sides and terraces; transport of alluvial and flood plain formation	Bank erosion and scour, particularly on outside of bends.

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Stream Types and Characteristics
Plains and Gentle Slopes

General type of country or slopes	Type of stream or crossing	Typical materials exposed in channel	Dominant channel processes	Possible hydraulic problems
Plains; streams with flat slopes	Meandering alluvial river	Sand and silt	Reworking of floodplain deposits by systematic migration of meanders; erosion of valley sides and terraces	Bank erosion caused by continual shifting of meanders; sand bed especially susceptible to scour
	Low-velocity stream in organic terrain, often with contorted windings	Silt and sand	Bank erosion; deep scour holes	Provision for large overbank flows
	Lake or inundated flood plain crossing	Silt, clay, organic material	Wave action	Soft foundations

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Examples of River Erosion
Road 13N km 470+500

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Examples of River Erosion
Road 13N km 366+000 & 368+000

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Examples of River Erosion
Road 8 km 118+000 to 128+800

Control Measures
Retreat & Realignment

- Only feasible where land use, terrain and topography allow – often not feasible in hilly areas
- Can result in issues over land ownership if properties or farmland are affected
- Can potentially avoid high construction costs associated with bank protection and river engineering work

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Control Measures - Engineering Works

Rip Rap

- Layer of heavy stone which protects softer materials of the river bed and banks
- Must be heavy enough not to be moved by peak flow velocities (storm/flood events)
- Flexible system that can't 'break'
- Easy to construct
- Natural appearance, can promote vegetation growth
- Large stones difficult to quarry and transport
- Maintenance and repair required

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Control Measures - Engineering Works

Gabions

- Flexible and performance not impaired by slight settlement
- Easy to maintain
- Commonly used constructed method in Laos
- Natural appearance, can promote vegetation growth

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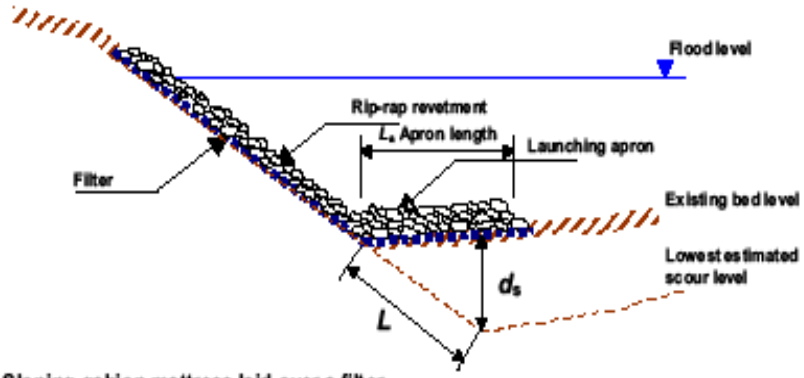
Control Measures - Engineering Works

Mortared Masonry & Concrete

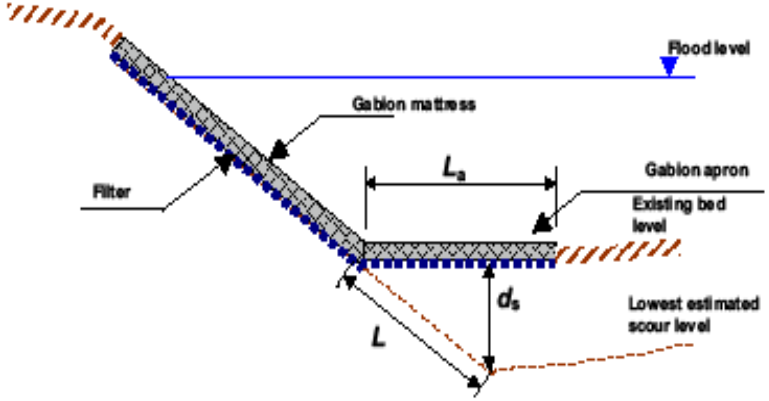
- Mortared Masonry unsuitable for river bank protection works – too rigid and doesn't drain.
- Mortared Masonry suitable for road side drainage and some slope drainage.
- Concrete has similar disadvantages to Mortared Masonry although is stronger.
- Concrete sometimes suitable if protected from scour.

Examples of Hard Revetments

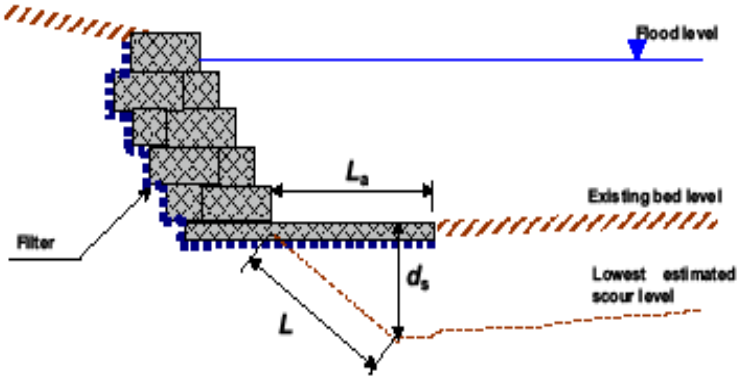
Sloping rip-rap revetment with launching apron on the bed of the river at foot of the slope



Sloping gabion mattress laid over a filter



River wall formed of gabion boxes protected at the base by a gabion mattress



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Control Measures – 'Soft' Revetments

Soda Method

- Introduced to Mekong River in Vientiane by JICA Project
- Soda Mattresses Intended to be a 'low cost' method with following characteristics:
  - Use only locally available material such as fascine and stones
  - Can be built on various sizes depending on the particular site
  - Environmentally friendly
- Flexible and when used at the base of a revetment, it can accommodate movement and scour – similar to Gabions but lower cost.

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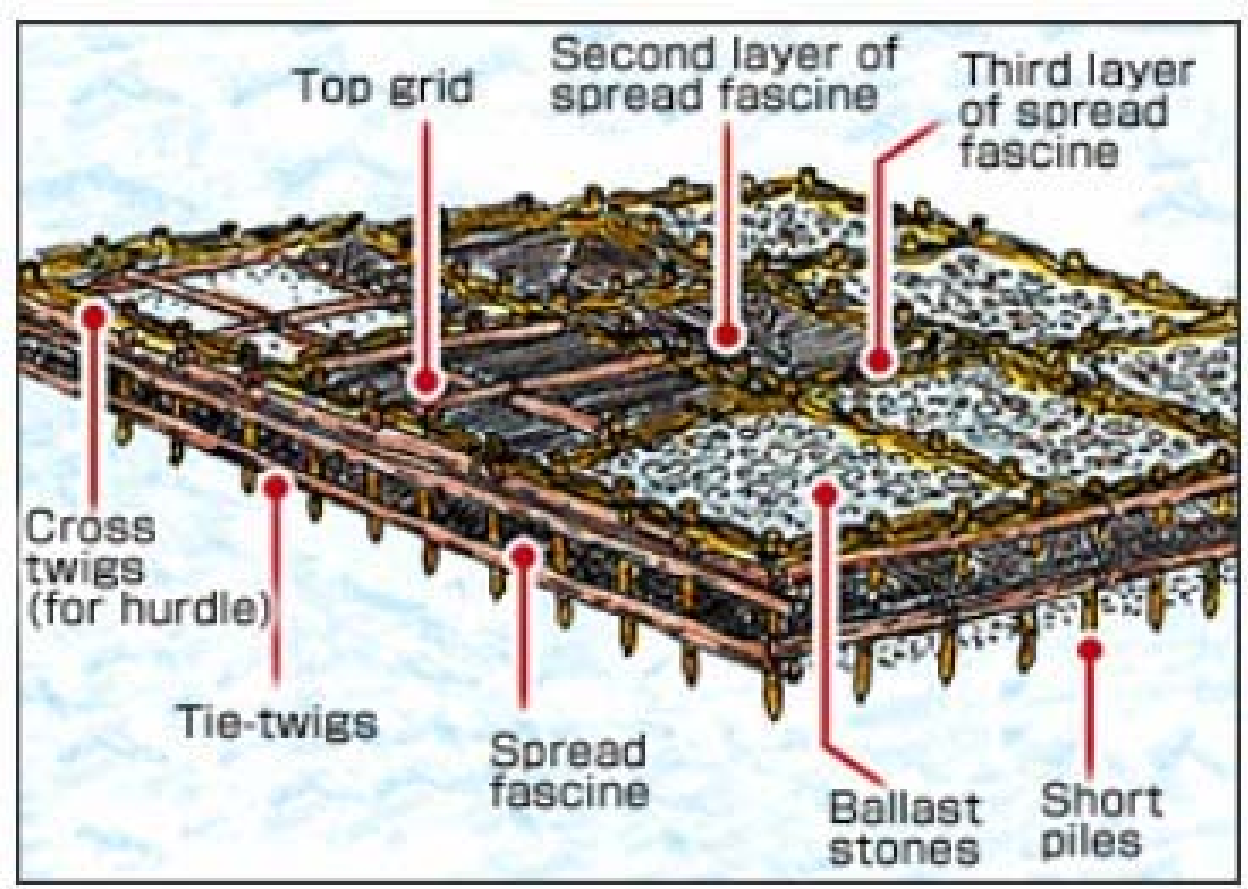
Soda Mattress



Source : JICA

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Vegetation

- Vegetation can be used above the water level - see bio-engineering Themes
- Vegetation alone for river bank work is unsuitable as it does not survive periods of flooding
- Reinforced vegetation can survive the higher flow velocities. Reinforcement options include:
  - Man made grids (Enkamat etc)
  - Gabions

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Enkamat (Maccaferri)

Source : Maccaferri

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Selection and Design

Type of protection	Maximum velocity (m/s)	Description	Remarks
Bare Soil	0.75	Fine sand	Quoted velocities assume that there is colloidal material in suspension, velocities are 30 to 50% lower for water with no material in suspension.
	0.75	Sandy Clay	
	0.90	Soft clays	
	1.05	Muds	
	1.50	Coarse sand	
	1.50	Medium clay	
	1.85	Gravel	
	1.70	Shingle	
	1.85	Hard clay	
Rip-rap	3.80	d50 stone 200 kg	Requires 0.8 m layer
	4.60	d50 stone 600 kg	Requires 1.2 m layer
	5.60	d50 stone 2,000 kg	Requires 1.8 m layer
0.30m Gabion Mattress	5.50	d50 stone 100 mm	
	6.40	d50 stone 125 mm	

The relatively poor performance of rip-rap should be noted

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Selection and Design

Type of protection	Maximum velocity (m/s)	Description	Remarks
Gabion Box	7.60	d50 stone 150 mm	
	8.00	d50 stone 190 mm	
Unreinforced Grass	2.00		
Enkamat 7003	5.20	30 minute, vegetated	Test values
	3.60	50 hour, vegetated	Test values
Enkamat 7920	5.80	30 minute, vegetated	Test values
	4.20	50 hour, vegetated	Test values
Soda Mattress	No data		4-5 m/s measured at JICA trial sites in Vientiane
Concrete	>8.00		

Measurement of Water Velocity

- **On-site measurements can be made during flood conditions – sufficient for Mekong River where flood peak is long duration and reliable.**

- **For tributary rivers with no data Manning's Equation can be used to obtain mean flow velocity – this must be factored to obtain channel velocity as follows:**

Location	Factor for mean flow velocity
Straight reach	1.0
Outside bend	1.33
Inside bend	0.67
At bridge abutments etc	1.50