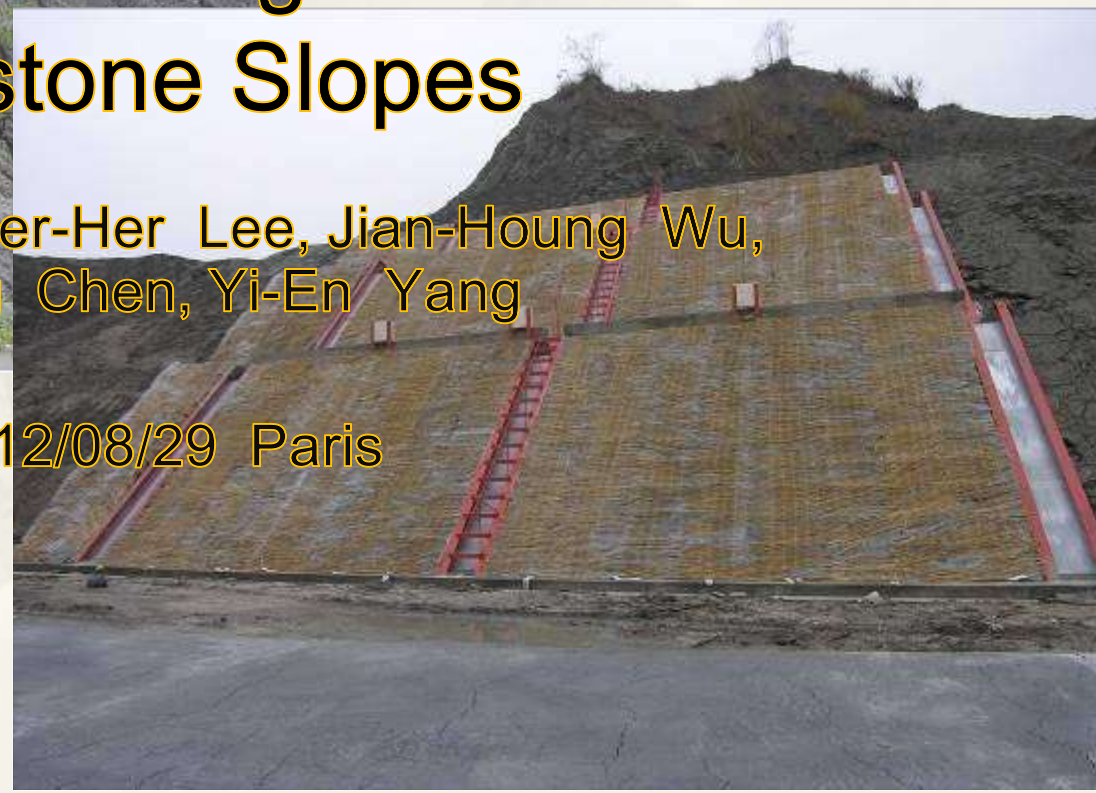
# Applying New Soil-Tire-Vegetation Method (STV) to Mitigate the Surface Erosion at the High-Gradient Mudstone Slopes



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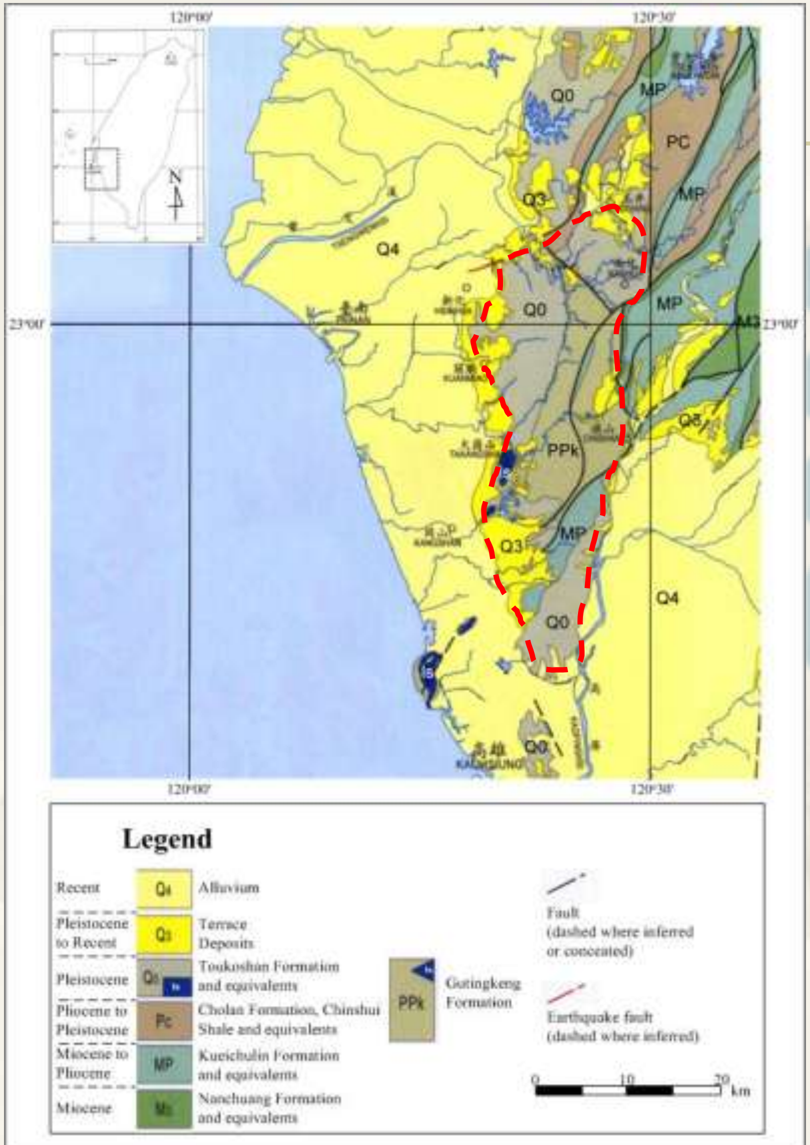
Mudstone in the foothills of Southwestern Taiwan is named Gutingkeng mudstone.

| | |
|---|---|
| **Age** | Pliocene marine sedimentary rocks |
| **Composition** | Silt (70%) & clay (20%) |
| **Color** | Gray or Dark gray |
| **Slaking index** | Id2 is about 50% |

**Young, Bad cementation, Low durability**




Geological map of Southwestern Taiwan

**Mudstone easily collapses when the rock absorbs water**

**Rainfall is usually concentrated in the rainy season in Southwestern Taiwan**

May to September

**Mudstone slope surface is often scoured by the rainfall to cause the difficulty of vegetation growth.**

Badlands terrain at Southwestern Taiwan

**Gullies and bare ground is typical landscape**

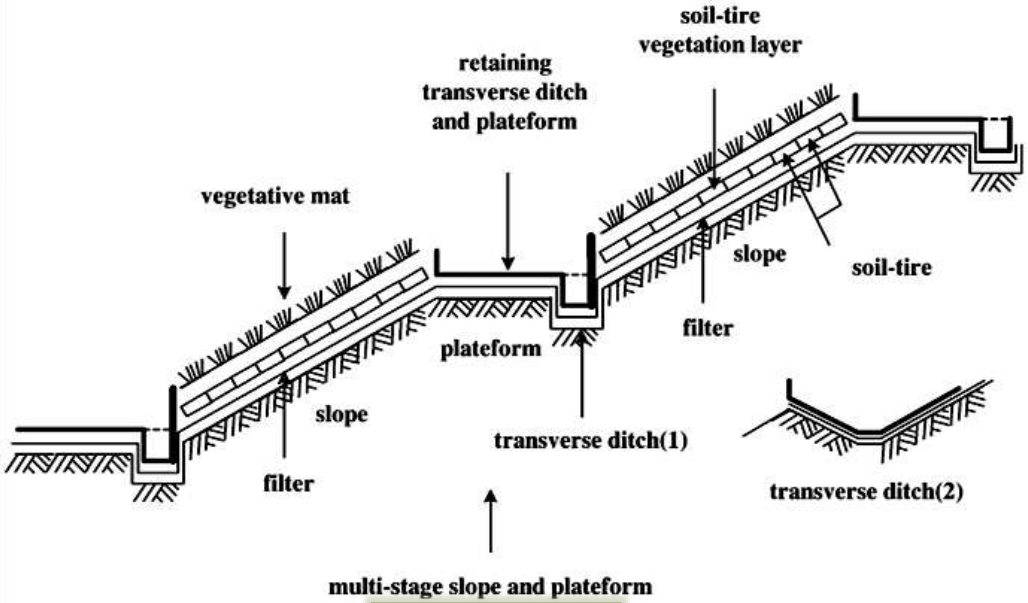
- Must consider two keys of mudstone slope protection method (Lee, 1992)

**Height** — Designed to be multi-stage slopes to stabilize the slope and to reduce slope erosion. The height of each stage is less than 5 m.

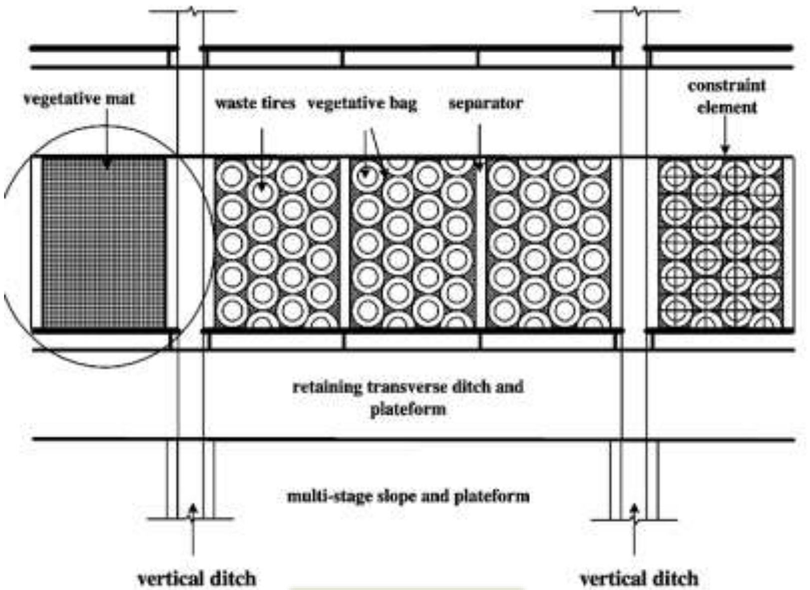
**Angle** — The mudstone slope angle should less than 40°, if not, must use the civil engineering countermeasure to protect the slope surface.

1. Construct good surface drainage system to constrain the flow path of water run-off.
2. Prevent the loss of fine-grained soils, and keep the surface water out of the slope.
3. Design proper slope length and height for the mudstone slope. Multi-stage slopes are applied to a high and long slope.
4. Provide adequate structure strength to fight against the swelling pressure of mudstone.
5. Decrease the weight of the structure to avoid slope failure due to the heavy countermeasure structures.
6. Include the concept of ecology and landscape when designing the slope protection structures

STV was proposed in 2004 and the first attempt is applied STV to protect a 35° mudstone slope.




Vertical section




Cross section

**H-beam**: Form the grid element and let waste tires can be arrayed

**Waste tires**: Fill with the vegetative bags as the vegetative zone, to improve the slope vegetation and to prevent from erosions and weathering

**Geotextile**: Prevent the loss of fine-grained soils

| Date (day/month/year) | Cumulative Rainfall (mm) | Soil Erosion (g/m$^2$) | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Original slope | STV slope | | | | | |
| | | | $D_1$ | $D_2$ | $E_1$ | $E_2$ | $F_1$ | $F_2$ |
| 17/12/2004 | 96 | 860 | 424 | 192 | 274 | 146 | 300 | 216 |
| 10/04/2004 | 167 | 232 | 58 | 136 | 13 | 50 | 41 | 75 |
| 22/05/2005 | 252 | 1716 | 178 | 33 | 12 | 52 | 114 | 50 |
| 24/06/2005 | 1,188 | 11,486 | 193 | 26 | 47 | 61 | 149 | 107 |
| 16/07/2005 | 64 | 595 | 276 | 34 | 25 | 76 | 86 | 121 |
| 26/07/2005 | 723 | 4,897 | 86 | 39 | 9 | 86 | 148 | 28 |
| 08/09/2005 | 869 | 6,393 | 55 | 16 | 27 | 10 | 56 | 9 |
| 26/11/2005 | 194 | 1,486 | 22 | 7 | 12 | 5 | 24 | 4 |
| Total | 3,553 | 27,665 | 1,775 | | 905 | | 1,528 | |
| Reduce percentage (%) | - - | - - | 93.58 | | 96.73 | | 94.48 | |

**Erosion reduced more than 90%.**

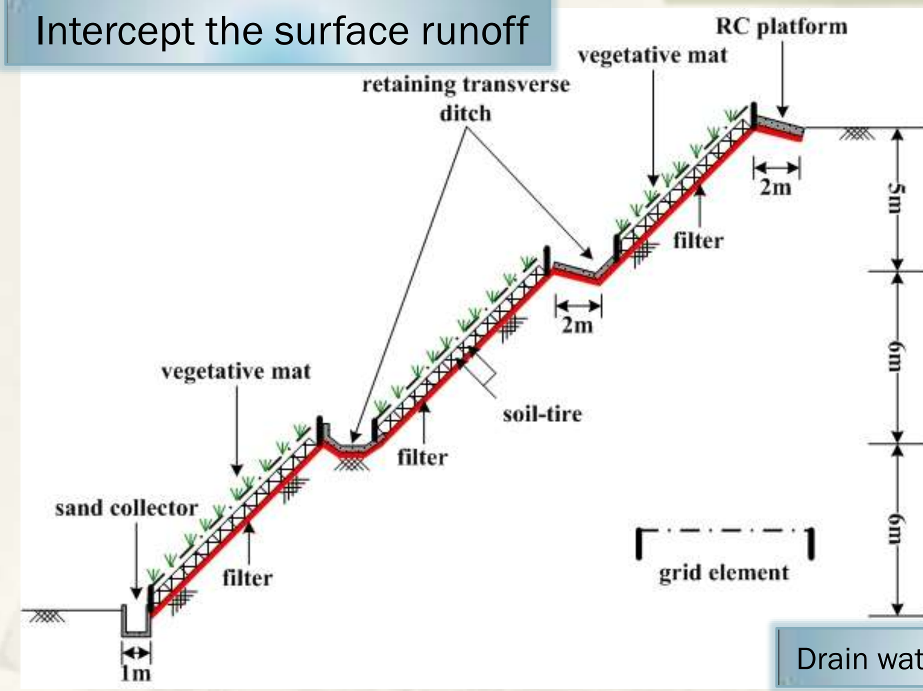
**STV can protects the mudstone slope very well**

# Try to use STV on the 45° mudstone slope

- The nature slope was cut into a slope with three 45° stages, and the slope protection work covered an area of 390 $m^2$.

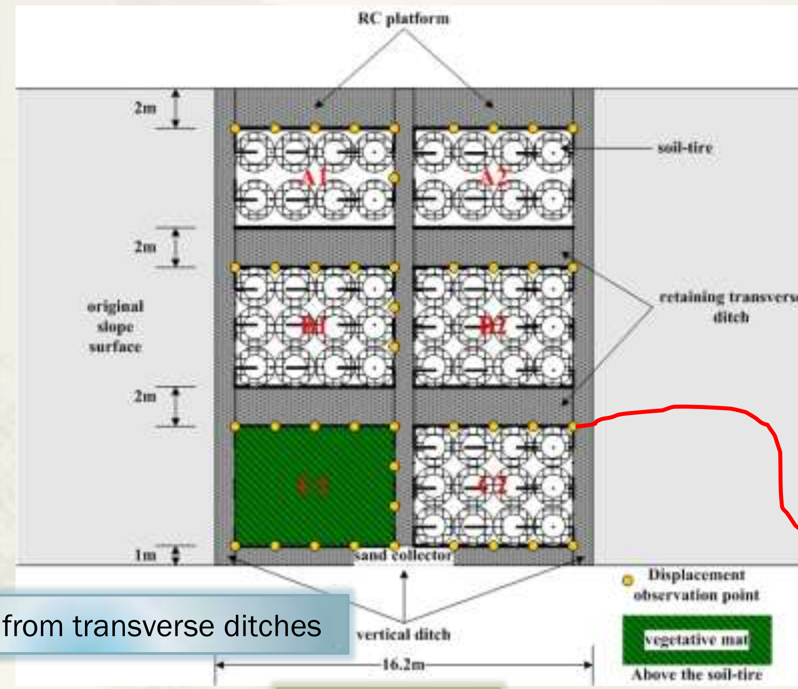
1.Bare the weight of the grid element
2.Avoid the water runoff infiltrating to the mudstone

Intercept the surface runoff




Vertical section

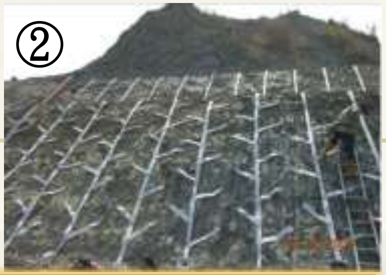
Drain water from transverse ditches




Cross section

Set up 41 displacement monitoring points

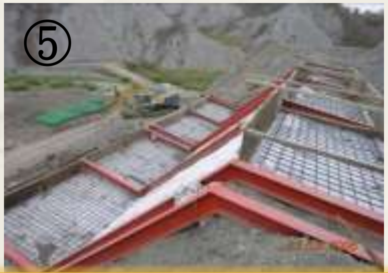

Shape the 3-stage slope and the plateform




Install the fabric drain


Put the geotextile sheet


Install the grid elements




Construct transverse ditches and RC-platform


Place waste tires in the grid and fill with vegetative bags

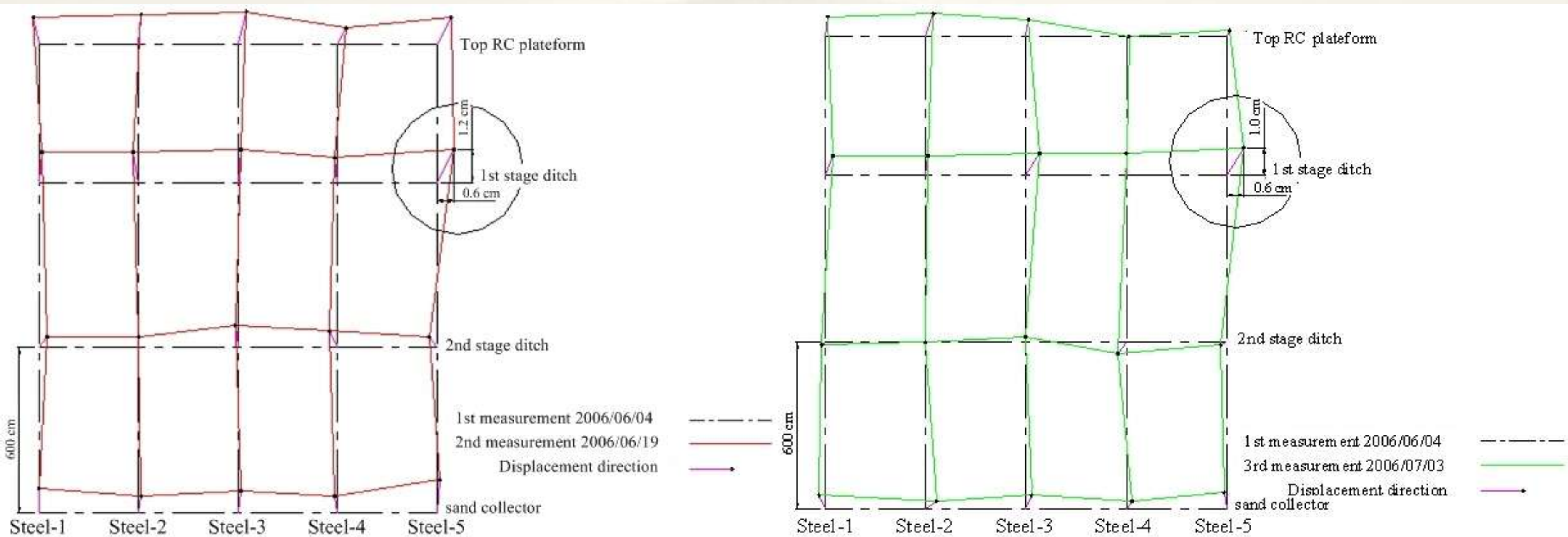

construct longitudinal ditches


Put the vegetative mat on the grid and complete the work

# STV can provide a good growing conditions of vegetation

| Date (day/month/year) | Vegetation coverage (%) | | | | | | |
|---|---|---|---|---|---|---|---|
| | original slope | STV slope | | | | | |
| | | A1 | A2 | B1 | B2 | C1 | C2 |
| 04/06/2006 | <5 | 15 | 20 | 10 | 15 | 25 | 15 |
| 10/06/2006 | <5 | 25 | 30 | 15 | 20 | 25 | 20 |
| 23/06/2006 | <5 | 30 | 35 | 40 | 35 | 45 | 35 |

**The STV grid element remained stable after heavy rainfall at the high gradient mudstone slope..**




The largest horizontal displacement is only 0.6 cm at the steel-5.

| Period (day/month/year) | Cumulative Rainfall (mm) | Soil Erosion (g/$m^2$) |
|---|---|---|
| 01/04/2006~20/05/2006 | 222 | 2,000 |
| 21/05/2006~22/06/2006 | 893 | 21,000 |

**WHY ??**

As the cumulative rainfall increased roughly 4 times, the erosion amount increased 10 times.

**Reason**

1. Vegetation bags were difficult to be fixed in waste tires on the steep slope.
2. The heavy rainfall eroded the vegetation soil seriously.
3. The original slope surface without STV erodes seriously. And the eroded soil flew into the transverse ditch and the sediment pool, and affected the erosion data.

**Solution**

Improve the fix method of vegetation bags.

1. Because of the STV grid element deformed only 0.6 cm horizontally. That indicates STV have high stability at high gradient mudstone slope

2. The vegetation coverage rate was about 45% two month later, shows STV can improve vegetation grow condition at mudstone slope.

3. If the STV vegetation zone can be stabilized at the high gradient mudstone slope, that can solve the soil loss and scour problems, and promote the vegetation growth effectively.

4. The new STV is an effective, green and ecological technique for the mudstone slope protection.

| | |
|---|---|
| H-beam | Light, and decrease the amount of concrete. |
| Waste tires | Waste recycling |
| Vegetation bags | Fill with the alluvial soils of the eroded in-situ mudstone slope. |

STV complete (2006)

2008/02/19

2008/05/09

2010/07/16

2012/02/06

After almost 5 years

Bare slope surface erodes about 30 cm. But STV slope still keep original look, but a lot of vegetation.

# THE END
# THANKS FOR YOUR ATTENTION

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