THE APPLICATION OF VETIVER SYSTEM IN COMBINATION WITH GEOTECHNICAL REMEDIAL MEASURES FOR IMPROVING THE STABILITY OF SLOPES

SURAPOL SANGUANKAEO

LALIT SAWASDIMONGKOL AND PREECHA JIRAWANWASANA

DEPARTMENT OF HIGHWAYS, THAILAND (ICV-6, Danang, Vietnam, 5-8/5/2015)
1) BACKGROUND OF THE PROJECT

On 24-30 March, 2011: Precipitation was 922 mm.

From Tripopp Pongsuwan, 2012
2) DESCRIPTION OF THE STUDY AREA

RUBBER FOREST PLANTATION TERRAIN

RURAL ROAD

LANDSLIDES

FOUR CONSECUTIVE LANDSLIDES OF 150 M., ALONG THE ROAD
3) THE OBJECTIVE OF THIS STUDY

TO SELECT THE MOST APPROPRIATE VETIVER TO BE PLANTED IN THE SHADED AREAS AND SUBSEQUENTLY MOVED TO FOREST NATURAL AREAS AND RUBBER FOREST PLANTATION.

TO USE APPROPRIATE TOOLS AND TECHNIQUES TO PREVENT SOIL EROSION AND SHALLOW SEAT FAILURE. THE RESULTS OF THIS STUDY WILL BE USED AS A TOOL FOR SETTING UP AND ENHANCING THE APPLICATION OF VS FOR NATURAL DISASTER REDUCTION.
4) DESCRIPTION OF LANDSLIDES AND GEOTECHNICAL ASPECTS

LANDSLIDE SITE NO. 1

- SHALLOW LANDSLIDE: 3 M.
- EROSION: 50 M.
4) **DESCRIPTION OF LANDSLIDES AND GEOTECHNICAL ASPECTS**

**LANDSLIDE SITE NO. 2**

- **LANDSLIDE SCARP**

Diameter: 65 m.

**2012/12/18**
4) DESCRIPTION OF LANDSLIDES AND GEOTECHNICAL ASPECTS

LANDSLIDE SITE NO. 3
4) DESCRIPTION OF LANDSLIDES AND GEOTECHNICAL ASPECTS

LANDSLIDE SITE NO. 4

Rubber Forest Plantation Terrain

Landslide Scarp

110m.
SHALLOW LANDSLIDE

3 M.

EROSION

2012/12/18
DRIVEN SOIL NAILS

REMEDIAL MEASURES FOR MAIN SCARP STEEPNESS LESS THAN 80 DEGREES (SITE NO. 1, 3 AND 4)

SHADE TOLERANT SPECIES

Vetiver (Shade tolerant species)
Planting in rows is 30 cm. apart

HYDROSEEDING

3 M.

DRIVEN SOIL NAILS

HYDROSEEDING/ Erosion control mat

VETIVER 
Vetiveria zizanioides Nash.
Planting in rows is 30 cm. apart

GREEN GABION

Gabion (Alu-Zinc) size (4.0x1.0x1.0 m.)
Gabion (Alu-Zinc) size 1.5x1.0x1.0 m.
Gabion (Alu-Zinc) size 4.0x1.0x1.0 m.
Gabion (Alu-Zinc) size (4.0x1.0x1.0 m.)
Gabion (Alu-Zinc) size (4.0x1.0x0.5 m.)

Geotextile 200 g/m²
Existing ground surface of slope
REMEDIAL MEASURES FOR MAIN SCARP STEEPER THAN 80 DEGREES
(SITE NO. 2)

**GREEN RENO-MATTRESS**
Green Reno-Mattress (Filled with soil bags containing selected grass seeds)

**VETIVER**
Vetiveria zizanioides Nash.
Planting in rows is 30 cm. apart

**SHADE TOLERANT SPECIES**
Vetiveria nemoralis (Shade tolerant species)
Planting in rows is 30 cm. apart

**DRIVEN SOIL NAILS**
Driven Soil Nail (Anti-rust coating)
RB Ø 9 mm., L = 1.50 m. @ 1.0x1.5 m.

**GREEN GABION**
Soil bags containing selected grass seeds

Gabion (Alu-Zinc) size (4.0x1.0x1.0 m.)

Geotextile 200 g/m²

Existing ground surface of slope
6) FIELD OPERATION PROCEDURE AND REHABILITATION

6.1) TOE SLOPE PORTION: GREEN GABION

Vetiveria zizanioides Nash

OCTOBER, 2014

OCTOBER, 2014
JUTE SOIL BAGS 50X30X13 CM. (70X40X15 CM)

LUCY, ALTRATUM, LEGUME

GERMINATION OF GRASS
TOP VIEW: THE COMPLETION OF WORK

1 MONTH AFTER THE COMPLETION OF WORK

GREEN GABION

SEPTEMBER, 2014

GREEN GABION

OCTOBER, 2014
THE COMPLETION OF WORK

REPLACEMENT OF MAIN SCARP WITH A GREEN GABION USING VETIVERIA ZIZANIIOIDES NASH

DECEMBER, 2014
GREEN GABION

4 MONTHS AFTER THE COMPLETION OF WORK

JANUARY, 2015
6) FIELD OPERATION PROCEDURE AND REHABILITATION

6.2) MAIN BODY PORTION OR SLIDING MATERIALS

Vetiveria zizanioides Nash (Close-spaced Plantation)

VETIVER SYSTEM

75,000 SLIPS OF VETIVER (SURAT THANEE ECOTYPE) WERE PLANTED ON THE MAIN BODY OF LANDSLIDES OCTOBER, 2014
CLOSETLY-SPACED PLANTATION, PLANTING IN ROW 30 CM. APART AND IN CLUMPS WITH 5-10 CM. AS PIONEER PLANT ON BARREN AREA OF SLIDING MATERIAL.

Vetiveria zizanioides Nash

SLIDING MATERIAL

LANDSLIDE SCARP

AUGUST, 2014

Vetiveria zizanioides Nash

SLIDING MATERIAL

OCTOBER, 2014

30 CM.
Vetiveria zizanioides Nash

CAPABILITY OF BLOCKING OR CONTROLLING WEEDS

OCTOBER, 2014
THE COMPLETION OF WORK

Vetiveria zizanioides Nash

MAIN SCARP

GREEN GABION

DECEMBER, 2014
6.3 ) MAIN SCARP PORTION ( STEEPER THAN 80 DEGREES )

6.3.1) GREEN RENO-MATTRESS

INSTALLATION OF DRIVEN SOIL NAILS
9 MM. IN DIAMETER
1.5 M. LONG, 0.5 M. SPACING

OCTOBER, 2014

50 CM.
2 MONTHS AFTER THE COMPLETION OF WORK
6.3) MAIN SCARP PORTION ( STEEPNESS LESS THAN 80 DEGREES )

6.3.2) HYDROSEEDING / EROSION CONTROL MAT

MADE FORM POLYPROPYLENE OR POLYAMIDE

AUGUST, 2014
GRASS SEED

OCTOBER, 2014

GERMINATION OF GRASS ON 10 DAYS AFTER SEEDING
HYDROSEEDING

GREEN GABION

DECEMBER, 2014
HYDROSEEDING / EROSION CONTROL MAT
6.4) UPPER SURFACE OF FAILED SLOPE PORTION

6.4.1) SHADE TOLERANT VETIVER

Vetiveria zizanioides Nash

LANDSLIDE SCARP

GREEN GABION

SHADE TOLERANT VETIVER ECOTYPES

SEPTEMBER 2014
2 MONTHS AFTER PLANTING
6.4 UPPER SURFACE OF FAILED SLOPE PORTION

6.4.2 DIVERSION DITCHES

DIVERSION DITCHES

- Vetiveria nenorala (Shade tolerant species)
- Planting in rows is 30 cm. apart
- Green Reno-Mattress (Filled with soil bags containing selected grass seeds)
- Vetiveria zizaniodes Nash
- Planting in rows is 30 cm. apart
- Each diversion ditch
- Gabion (Alu-Zinc) size (4.0x1.0x1.0 m.)
- Geotextile 200 g/m²
- Existing ground surface of slope
- Driven Soil Nail (Anti-rust coating) R.D. ø 9 mm. L= 1.50 m. @ 1.0x1.5 m.

2 MONTHS AFTER PLANTING
6.4) UPPER SURFACE OF FAILED SLOPE PORTION

6.4.3) DRIVEN SOIL NAILS

4 -- 10 NAILS / HOUR

SEPTEMBER, 2014
7) SLOPE STABILITY ANALYSIS

Display of trial slip surface for overall factor of safety.

\[
    \gamma' = 17.5 \text{ kN/m}^3 \\
    \phi' = 35^\circ
\]

FS = 1.194 (without the effect of vetiver root: \( c' = 0 \))

1.197 (with the effect of vetiver root: \( c' = 2.5 \text{ kPa} \))
7) SLOPE STABILITY ANALYSIS

Display of trial slip surface at lower portion

FS = 1.936 (without the effect of vetiver root : c' = 0)
2.007 (with the effect of vetiver root : c' = 2.5 kPa)

γ' = 17.5 kN/m^3
φ' = 35°
7) SLOPE STABILITY ANALYSIS

Display of trial slip surface at upper edge of the slope portion

FS = 1.127 (without the effect of vetiver root: c' = 0)

FS = 1.206 (with the effect of vetiver root: c' = 2.5 kPa)

γ' = 17.5 kN/m³

Ø' = 35°
8) OBSERVATION AND ANALYSIS OF PLANT GROWTH

**MAIN BODY PORTION OR SLIDING MATERIALS**

Vetiveria zizanioides Nash

OCTOBER, 2014

4 - 6 HOURS, > 2 - 3 NEW SHOOTS DEVELOPMENT / PLANT, 0.8 - 1.5 M. HEIGHT.

**UPPER SURFACE OF FAILED SLOPE PORTION**

Vetiveria nemoralis

OCTOBER, 2014

2 HOURS, SURVIVAL RATE 20%, MAINLY NONE OF NEW SHOOT HAD BEEN DEVELOPED, 30-70 CM. HEIGHT
8) OBSERVATION AND ANALYSIS OF PLANT GROWTH

SITE NO. 1

2.5 HOURS,
Survival rate 15%, None of new shoot developed
1 new shoot
0.5-0.7 cm. height

4 HOURS,
1-3 new shoots developed,
0.8-1.0 m. height

MAIN BODY PORTION OR SLIDING MATERIALS

UPPER SURFACE OF FAILED SLOPE PORTION (PLANTING IN THE SHADE AREA)

JANUARY, 2015
SITE NO. 2
MAIN BODY PORTION OR SLIDING MATERIALS

EXPOSED TO SUN LIGHT FOR 3 HOURS

1-3 NEW SHOOTS DEVELOPED, 0.8-1.2 m. HEIGHT

JANUARY, 2015

UPPER SURFACE OF FAILED SLOPE PORTION (PLANTING IN THE SHADE AREA)

EXPOSED TO SUN LIGHT FOR 2 HOURS, SURVIVAL RATE 20%;

NONE OF NEW SHOOT DEVELOPED OR 1 NEW SHOOT, 0.3-0.5 CM. HEIGHT

JANUARY, 2015
Exposure to sun light for 5 hours:
- >2 - 3 new shoots developed, 1-1.5 m. height.

Exposure to sun light for 2.5 hours:
- Survival rate 12%
- None of new shoots developed or 1 new shoot, 0.4 - 0.6 cm.
SITE NO. 4
MAIN BODY PROOTION OR SLIDING MATERIALS

UPPER SURFACE OF FAILED SLOPE PROOTION (PLANTING IN THE SHADE AREA)

Exposed to sun light for 6 hours
> 2 - 3 Sprouting, 1-1.3 M.
JANUARY, 2015

Exposed to sun light for 2 hours,
Survival rate 7 %,
JANUARY, 2015

No sprouting or 1 sprouting,
0.5 - 0.7 CM.
JANUARY, 2015
9.1) It is necessary to understand the factors affecting the growth of vetiver, heterogeneity of soil made of landslide and mode of soil movement, before assigning this technique.

9.2) Appropriate pattern of the vetiver grassing for natural disaster reduction and remedial works on rehabilitation of landslide is closely-spaced plantations (planting in row is 30 cm. apart and in clump 5-10 cm spacing).
9.4) The application of driven soil nail as a method of soil reinforcement to increase the factor of safety is satisfactory, cost effective, easy to install.

9.5) The length of driven soil nail should not be less than 1.5 m.

9.6) After these damaged cut slopes had stabilized, there has been no sign of soil movement in any part of these cut slopes.

9.3) Shading played strongly negative effect on the growth of vetiver. Most of the vetiver planting in the shaded area did not survive which is unsustainable of the vetiver system. As a result, careful implementation is required.
THANK YOU