1.0 INTRODUCTION

1. The **POPULATION OF MALAYSIA** was estimated to be 30,572,466 people. This is an **INCREASE** of 1.51% compared to the previous year.

2. The escalating numbers of population leads to the **HIGH DEMAND FOR RESIDENTIAL AREA**.

3. **LIMITED AVAILABILITY OF FLAT LAND** causes the development to shift towards the hilly areas.

4. Rapid development on hilly areas affects **SLOPE STABILITY** and poses **RISKS** and **DETERIORATION** to properties and human lives.

5. Thus, **SUITEABLE SLOPE REMEDIAL WORKS** is **NECESSARY** to strengthen the slope and ensure the slope is safe.
HUMAN ERRORS INVOLVING SLOPE FAILURE

<table>
<thead>
<tr>
<th>Causes of landslides</th>
<th>No. of Causes</th>
<th>Percentage (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Design Errors</td>
<td>29</td>
<td>60</td>
</tr>
<tr>
<td>Construction Errors</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Design &amp; Construction Errors</td>
<td>10</td>
<td>20</td>
</tr>
<tr>
<td>Geological Features</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Maintenance</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>Total</td>
<td>49</td>
<td>100</td>
</tr>
</tbody>
</table>

Reference: Proceedings of the 3rd International conference on Geotechnical Engineering for Disaster Mitigation and Rehabilitation 2011

1.0 INTRODUCTION

According to the landslide forensic statistic data from year 2004 to 2007 of Slope Engineering Branch under the Public Works of Department Malaysia, 57% of landslides were due to human factors, whereas only 29% and 14% due to physical and geological factors, and most of the landslides occurred at man-made slopes.

Over 700 landslides were reported on 2015.

410 landslides occurred on federal roads.

290 happened along state roads.

2.0 HISTORY OF SLOPE FAILURE
SLOPE FAILURE AT BUKIT ANTARABANGSA (2008)

- Occurred on 6th December 2008
- Location: Bukit Antarabangsa, Ulu Klang, Selangor
- 14 Bungalows at Taman Bukit Mewah and Taman Bukit Utama destroyed
- 1.5 km from Highland Tower.
- Fatalities: 4 persons
- Injuries: 15 persons

LOSS OF PROPERTIES
SLOPE FAILURE AT SETIAWANGSA

- Emergency Response on Setiawangsa Slope Failure (28th December 2012)
- 1 house were badly damaged and houses evacuation were applied

BRIEFING TO PUBLIC & MEDIA ON SLOPE FAILURE AT SETIAWANGSA

- Briefing To Public
- Briefing To Media And Kuala Lumpur Mayor
- Briefing To Media At Site

DTM SETIAWANGSA SLOPE FAILURE

Bukit Setiawangsa Before Failure
DTM SETIAWANGSA SLOPE FAILURE

PROPOSED REMEDIAL WORK

SLOPE FAILURE AT BUKIT NANAS
SLOPE FAILURE AT RUMAH ANAK-ANAK YATIM DAN KEBAJIKAN MADRASAH AL-TAQWA, HULU LANGAT

-Occurred on 21st May 2011
-Location: Rumah Anak-anak Yatim dan Kebajikan Madrasah Al-Taqwa, Felcra Semungkis, Batu 14, Hulu Langat.
-The number of Victims: 25 persons
-Fatalities: 16 persons
-Injuries: 9 persons

LANDSLIDE AT KM52.4, KARAK HIGHWAY
As a reminder, repair works are very EXPENSIVE, and the reactive measures taken would give impact towards POLITICAL, MILEAGE, PUBLIC IMPRESSION and ECONOMY. Thus..........

Preventive is better than corrective, EVERYTIME.
# List of Remedial Work for Slope Failures (2008-2014)

<table>
<thead>
<tr>
<th>Location</th>
<th>Cameron Highlands RM 55</th>
<th>Jalan Kuala Terengganu - Jabor</th>
<th>Taskap Kenryir Selatan 37</th>
<th>Changkat Persekutuan Bukit Nenas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date of Failure</td>
<td>2008</td>
<td>2009</td>
<td>2010</td>
<td>2011</td>
</tr>
<tr>
<td>End of Construction</td>
<td>2009</td>
<td>2010</td>
<td>2013</td>
<td>2014</td>
</tr>
<tr>
<td>Area of Failure (sq.m / sq.ft)</td>
<td>65,110sq.ft</td>
<td>44,200sq.ft</td>
<td>94,220sq.ft</td>
<td>2,880sq.ft</td>
</tr>
<tr>
<td>Cost (RM)</td>
<td>5,400,000.00</td>
<td>1,300,000.00</td>
<td>3,300,000.00</td>
<td>4,300,000.00</td>
</tr>
<tr>
<td>Cost/Sq.ft</td>
<td>RM82</td>
<td>RM40</td>
<td>RM6</td>
<td>RM333</td>
</tr>
</tbody>
</table>

## Comparison Cost of a Bungalow and 1 Storey-Terrace House

<table>
<thead>
<tr>
<th>Type</th>
<th>Bungalow</th>
<th>1-Storey Terrace</th>
</tr>
</thead>
<tbody>
<tr>
<td>Build Up Size</td>
<td>4000 sq.ft</td>
<td>1500 sq.ft</td>
</tr>
<tr>
<td>Land Cost/Sq.ft</td>
<td>RM 40</td>
<td>RM 40</td>
</tr>
<tr>
<td>Land Cost/Unit</td>
<td>RM 160,000.00</td>
<td>RM 60,000.00</td>
</tr>
<tr>
<td>Construction Cost/Sq.ft</td>
<td>RM 150</td>
<td>RM 150</td>
</tr>
<tr>
<td>Construction Cost/Unit</td>
<td>RM 600,000.00</td>
<td>RM 255,000.00</td>
</tr>
<tr>
<td>Cost per Unit Sq.ft</td>
<td>RM 760 000.00</td>
<td>RM 285 000</td>
</tr>
<tr>
<td>Cost per Sq.ft</td>
<td>RM 190 /sq.ft</td>
<td>RM 190 /sq.ft</td>
</tr>
</tbody>
</table>

### Jalan Changkat Persekutuan Kuala Lumpur

- **5 Bungalow** @ RM 4,300,000.00 (12,880 sq.ft)
- **14 1-Storey Terrace** @ RM 4,300,000.00 (1500 sq.ft)
### COMPARISON COST of HOUSING DEVELOPMENT & SLOPE REMEDIAL

<table>
<thead>
<tr>
<th>NO</th>
<th>LOCATION</th>
<th>COST OF CONSTRUCTION</th>
<th>BUNGALOW 4000 SQ.FT</th>
<th>TERRACE 1300 SQ.FT</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Bukit Nenas (93,260sq.ft)</td>
<td>RM 13 300 000.00</td>
<td>20</td>
<td>23</td>
</tr>
<tr>
<td>2</td>
<td>Tasik Kenyir Sekyen 36 (94,200sq.ft)</td>
<td>RM 3 300 000.00</td>
<td>6</td>
<td>18</td>
</tr>
<tr>
<td>3</td>
<td>Cameron Highland KBA3.5 (85,110sq.ft)</td>
<td>RM 3 400 000.00</td>
<td>7</td>
<td>18</td>
</tr>
<tr>
<td>4</td>
<td>Chongkot Penakurian (7,280sq.ft)</td>
<td>RM 4 300 000.00</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>5</td>
<td>Jalan Kuala Terengganu – Jabor (44,200sq.ft)</td>
<td>RM 1 300 000.00</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>

### 3.0 PROBLEMS STATEMENT

...An analysis of various problems encountered during slope remediation projects...

### WHAT ARE THE BEST METHODS TO PREVENT SLOPE FAILURE FROM OCCURRING?

...A discussion on the most effective techniques for slope stabilization and protection...

...An exploration of case studies and practical solutions to prevent slope failures...

...A comprehensive review of the latest research and methodologies in slope remediation techniques...
WHAT ARE THE SUITABLE METHODS FOR SLOPE REMEDIAL?

1. GRAVITY WALL
2. CANTILEVER WALL
3. PILING WALL
4. MSE WALL

1. SOIL NAIL
2. GROUND ANCHOR
3. GEOTEXTILE

1. HYDROSEEDING
2. TURFING
3. PLANTATION
4. SHORTCRETE

4.0 SLOPE REMEDIAL

- Retaining Wall
- Soil Reinforcement
- Surface Erosion Control
Soil nailing can prevent landslides by inserting steel reinforcement bars into the soil and anchoring them to the soil.

Soil nailing is a technique used to bring soil stability in areas where landslides might be a problem.

WHAT IS SOIL NAILING?

TERMINOLOGY OF SOIL NAIL

Steel Bearing Plate
(200x200 mm)
Subject to calculation

Nail Inclination:
15° - 20°

Critical Slip Circle

Reinforcement Bar Diameter = 25, 32 & 40 mm

length of Soil nail subject to avoid critical slip circle

Sources: Soil Nailing Design Malaysia Perspective
(Chow Chee Meng & Tan Yean Chin)
TERMINOLOGY OF SOIL NAIL

Horizontal Spacing of nail: Typically 1.5m to 2.5m
Vertical Spacing of nail: Typically 1.5m to 2.5m
Minimum plate width of 200mm
Minimum plate thickness 19mm
Concrete cover typically 50-75mm thick

Sources: Soil Nail Design Malaysia Perspective (Chow Chee Meng & Tan Yean Ooi)

TYPICAL DETAIL OF SOIL NAIL

SITE IS CLEARED
SLOPE IS CUT
SOIL NAILING IS INSTALLED

Insert Bar and Grouting
Steel Plates
Shortcrete
Hole is drilled
STRUCTURAL CAPACITY OF SOIL NAIL

Ultimate structural capacity, \( P = 0.87 \times f_y \times A_s \)

Where:
- \( f_y \) = characteristic strength of steel bar
- \( A_s \) = reinforcement area

\( A_s = \pi \cdot d^2 / 4 \)

<table>
<thead>
<tr>
<th>Steel Bar Diameter (mm)</th>
<th>Cross-sectional Area of Pile, ( A_c ) (mm²)</th>
<th>Ultimate structural capacity, ( P ) (kN)</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>490</td>
<td>((0.87 \times 460 \text{ N/mm}^2 \times 490 \text{ mm}^2) / 1000) = 196 kN</td>
</tr>
<tr>
<td>32</td>
<td>804</td>
<td></td>
</tr>
<tr>
<td>d0</td>
<td>1,256</td>
<td></td>
</tr>
</tbody>
</table>

*Normal Size Use in Malaysia

Structure Capacity (refer BS 8110: Clause 7.4.4.3.1)

Structural Capacity Soil Nail vs Steel Bar Size

SENSITIVITY ANALYSIS
SOIL NAILING WORK SEQUENCES

**STEP 1**
Clearing, scaling and trimming

- Clear and remove from site all obstacles over the areas for the construction.
- Trimming stages to perform proposed slope inclination.

SOIL NAILING WORK SEQUENCES

**STEP 2**
Survey & Paving soil nail point

- Survey soil nail point to measure actual quantity of soil nail.

SOIL NAILING WORK SEQUENCES

**STEP 3**
Preparation of Soil Nail Works

- Installation of staging to perform soil nailing works.
SOIL NAILING WORK SEQUENCES

STEP 4
Drilling soil for installation of soil nail

Drilling soil nail point using drilling machine

Air Compressor

SOIL NAILING WORK SEQUENCES

STEP 5
Installation of soil nail

Inserting reinforcement bar (size as per design) in the hole

Reinforcement bar

SOIL NAILING WORK SEQUENCES

STEP 6
Grouting Process

Full grouting apply after inserting the reinforcement bar in the hole (cement grout as per design)

Reinforcement bar
SOIL NAILING WORKS SEQUENCES

STEP 7
Locking Soil Nail

Install soil nail plate and locking using bolt & nut.

SOIL NAILING WORK SEQUENCES

STEP 8
Testing – Pull Out Test

Perform pullout test to determine the performance of soil nailing based on design working load.

Pull Out Test
(According to BS 8081:1989)

• The pullout test on soil nail generally 1.5 times the working load as specified in BS 8081:1989.
• Load at this stage is called the pullout capacity.
• Tests are carried out to determine the strength of soil nailed structures.
PROGRESS PICTURE

SETTING UP FOR PULL OUT TEST

GAUGE METER READING WHILE PULL OUT TEST

PULL OUT TEST IN PROGRESS

Production Rate

<table>
<thead>
<tr>
<th>SPT VALUE</th>
<th>LENGTH (m)</th>
<th>TIMES REQUIRED / 1m LENGTH (Minutes)</th>
<th>TIMES REQUIRED / 6m LENGTH (Minutes)</th>
<th>TIMES REQUIRED / 12m LENGTH (Minutes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>1</td>
<td>2</td>
<td>12</td>
<td>24</td>
</tr>
<tr>
<td>20</td>
<td>1</td>
<td>6</td>
<td>36</td>
<td>76</td>
</tr>
<tr>
<td>30</td>
<td>1</td>
<td>7.5</td>
<td>45</td>
<td>90</td>
</tr>
<tr>
<td>40 - 50</td>
<td>1</td>
<td>10</td>
<td>60</td>
<td>120</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>SPT VALUE</th>
<th>AVERAGE DAILY RATE FOR 6M REINFORCEMENT</th>
<th>AVERAGE DAILY RATE FOR 12M REINFORCEMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>20</td>
<td>14</td>
<td>7</td>
</tr>
<tr>
<td>30</td>
<td>11</td>
<td>6</td>
</tr>
<tr>
<td>40 - 50</td>
<td>8</td>
<td>4</td>
</tr>
</tbody>
</table>

EXAMPLES OF SOIL NAILING USING MACHINERY

Excavator mounted drill rig
VIDEO SOIL NAIL

VIDEO OF SOIL NAIL WORKS

DEFINITION OF SHOTCRETE

Shotcrete is today an all-inclusive term that describes spraying concrete or mortar with either a dry or wet mix process through a hose and nozzle onto a surface.
CLASSIFICATION OF SHOTCRETE

DRY MIX
1. Dry materials including cement, aggregate, and ad-mixture are mixed together through a hose and then, at the nozzle via a water ring, water is injected evenly throughout the mix.
2. Dry mix usually uses for Slope protection surface (Shotcrete)

WET MIX
1. Materials including cement, aggregate, ad-mixture and water – are mixed together before being pumped through a hose
2. Wet mix usually uses for Grouting process for Soil Nail Work

DEFINITION OF GUNITE
Gunite is trademarked name that is incorrectly used to describe the dry mix shotcrete process

EXAMPLE APPLICATION OF SHOTCRETE
Shotcrete is used for slope surface protection
EXAMPLE APPLICATION OF SHOTCRETE

Shotcrete is used for concrete grouting of soil nail (Wet Mix)

INGREDIENT OF SHOTCRETE

SHOTCRETE, HIGH PERFORMANCE PRODUCT CONSISTING OF ...

Cement + aggregate + water + admixture

+ non-alkaline accelerator

MATERIALS AND MACHINERIES ON SITE
VEGETATION FOR SLOPE REMEDIAL

1. Vegetation influences slope stability by:
   • Providing cover for the impact of rain falling on slopes and prevent erosion on slope surface
   • Providing root systems by transferring shear stress in soil to the tensile resistance in the root

2. Types of vegetation:
   • Hydroseeding
   • Turfing

HYDROSEEDING

• Application of grass seed mixed with fertiliser and nutrient by spraying method over the ground
• The grass seed will grow eventually and the root of the grass will act as an organic reinforced fiber and hold the surface soil.
HYDROSEEDING WORKS

1. Grass seed, fertilizer and nutrients arrived at site.
2. Example of grass seed.
3. Spray grass seed.
4. Grass began to grow.
5. Finish hydroseeding works.

VIDEO OF HYDROSEEDING

Before and after hydroseeding

1. Video of hydroseeding before and after works.
Turfing is a direct application of grass with developed roots on a slope surface. The relatively matured grass will grow easier and extend its root into the soil to strengthen the overall surface.

Turfing Works

Limbang, Sarawak

Before Remedial

AFTER REMEDIAL
1. Soil Nailing
2. Hydroseeding

5.0 CASE STUDY OF REMEDIAL WORK

1. Soil Nailing
2. Hydroseeding
GUIDELINE FOR SLOPE STABILITY
(FACTOR OF SAFETY)

<table>
<thead>
<tr>
<th>GUIDELINE</th>
<th>FOS NATURAL SLOPE (GLOBAL/LOCAL)</th>
<th>FOS MAN-MADE SLOPE (GLOBAL/LOCAL)</th>
<th>FOS TEMPORARY SLOPE (GLOBAL/LOCAL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DBKL GUIDELINE</td>
<td>1.3</td>
<td>1.5</td>
<td>1.2</td>
</tr>
</tbody>
</table>

PANDUAN REKABENTUK CERUN (JKR)

GARIS PANDUAN PERANCANGAN PEMBANGUNAN DI KAWASAN BUKIT DAN CERUN BAGI WILAYAH PERSEKUTUAN KUALA LUMPUR, 2010
7.0 CONCLUSION

- Soil nail, vegetation and shotcrete are types of remedial works for SLOPE STABILIZATION and PROTECTION of slope surface.
- Understanding the methods of remedial works is crucial to ensure the works are ACCORDING to the STANDARD SPECIFICATION and SEQUENCES.
- KuLSIS is an example of comprehensive slope information system which acts as a tool for local authorities to MANAGE SLOPE EFFICIENTLY.