Topic:
Site Formation and slopeworks

Presentation prepared by
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Purpose of site formation is for:

- Forming of land by cutting & leveling of an uneven, sloppy or congested area.
- Accommodate building/s or other facilities which will be placed within the area.
- Form the land to the required orientation, shape or levels in order to accommodate such facilities.
- Provide the required back-up facilities including access roadways, drainage and other related services, both temporary or permanent in nature.
What works are usually involved in site formation projects in Hong Kong

• Clearance of the site including the removal of buildings or unwanted structures, shrubs and trees, surface soil and debris.

• Excavation by cutting into slope or other land area to get the required/extra land

• Leveling of the land by necessary cutting or filling to get a piece of flat or terraced land.

• Stabilize natural or new slope within the site.

• Construct retaining wall (as part of the slope stabilization or trimming to terraced land).

• Forming of access road and drainage system
Compare existing and new ground profile before and after the site formation.
Slope is very dangerous to hilly environment like Hong Kong – landslide in Po Shan Road/Kotewall Road, Mid Level, Hong Kong (18 Line 1972)
Building badly hit by the collapsing building sliding down from the upper position.
67人死亡
Classification of slope

Natural slope – in various conditions, including rock slope

Man-made slope - including cut-back slope or slope formed by filled material with adequate compaction, usually provided with surface and surface drainage

Man-made slope – formed mainly with the support by retaining structures
Components on a well-design and maintained man-made slope

1. Surface protection such as vegetation (rigid cover (masonry, plaster or shotcrete))
2. Surface drainage (including surface channels, catch pits and sand traps)
3. Subsurface drainage (including weepholes and subsoil drain etc.)
4. Other protective provision such as prestressed ground anchors

Note – try to avoid the placing of water-carrying services onto a slope
How a slope fail?

The most common failures in slopes of Hong Kong are come from the relatively shallow top soil, which further worsened by the depth of weathering and infiltration during rainstorms situations.

Slope can collapse easily by shear if the soil is nearly saturated and high pore pressure can be built up rapidly. The falling debris carried by its potential and momentum can rush down the slope at very high speed and travel a long distance causing huge damages.

Besides, highly decomposed rock in a slope may behave very similar to soil.
Typical failure profile for slope

Fill slope/retaining wall failures

Cut slope failure

Natural slope failures

Legend:
- Pre failure geometry
- Post failure geometry
- Extent of debris
Factors affecting the stability of slope

1. Topography and its surrounding physical conditions. Detail analysis can be done by appropriate site investigation process.

2. Geological conditions such as the nature and depth of its subsoil, degree of decomposition, or location of fracture etc. This data can be obtained by soil investigation.

3. Shear strength of the slope-forming materials. Data can be obtained using appropriate laboratory tests.

4. Surface and ground water condition

5. External loading and surcharges, such as from traffic, nearby structures, possible vibration etc.
Physical environment and Typographical conditions of a very large site

(Tseung Kwan O site formation)
Another example of large scale slope work as part of the site formation for the Tsing Yi North Coastal Road.
Effect of ground water affects the stability of slope.

Water trapped in soil causes movement, pushing down retaining wall.

Water drains through pipe, allowing wall to keep slope from moving.
Stability of slope can be effectively improved by the provision of an appropriately design drainage system, this cab be achieved by:

1. A surface drain system that is capable to discharge all the storm water within the rain water catchment area affecting the slope in a designated period of time (say, 200mm rainfall/hour).

A surface drain system usually consists of:
- surface channel
- stepped or trapezoidal channel
- catchpit or sand trap

2. A subsoil drain system that is laid below surface for the discharging of ground water and to maintain the water pressure be kept in a safe level

- filter layer behind the slope leading water to outlets
- weepholes
- cut-off drain
- subsoil drain pipe
Drainage detail for retaining walls

(a) CANTILEVER/COUNTERFORT

(b) CANTILEVER/COUNTERFORT used when (a) is not possible

(c) GRAVITY TYPE

(d) GRAVITY TYPE used when (c) is not possible
Forming surface drainage channel to slope
Surface drain before and after the formation
Final finished slope with drainage, retaining wall structure, surfacing treatment and other maintenance access path in place.
Drainage system for large area of slope
Protection and treatment to **Rock Slope**

Most rock slopes need some forms of treatment to ensure continued stability. Improvement methods include:

1. **Scaling** – loose blocks or boulders to be removed from exposed rock surfaces, this is usually done by manual method.

2. **Construct buttress support** – this is concrete or masonry gravity structure used to retain the unstable rock mass

3. **Dentition** – exposed soft material in a rock face be trimmed back. The resulting slot be filled with filter material and protected by masonry or concrete to prevent erosion.
Protection and treatment to Rock Slope (continue)

4. Sprayed concrete – apply concrete protection to zones of weak or highly fractured rock faces by spray-on method.

5. Dowel – a hole is drilled and provide untensioned steel bars, usually 25mm to 35mm dia. and 1m to 3m long, to stabilize a weak rock zone. The hole would be grouted afterward.

6. Rock bolt/nail – this is tensioned bar inserted into rock forming a short anchorage zone in rock so that an unstable slope area being reinforced by tension. Typical rock bolts are 25mm to 40mm in dia. 3m to 6m long, and have a tensile working load around 100kN.
Scaling a rock slope surface
Forming a steep slope in set-back benches and in phases starting from the top downward. Note that the upper benches are strengthened by soil nails.
Loosened rock needed to be scaled. Scaffold set-up prepared for the carrying of scaling a rock slope surface.
Loosened rock stabilized using closely placed dowel heads.
Cutting of rock using pneumatic (compress-air driven) breaking machine.
Cutting of rock using manual breaking method (by drilling row of holes and forced cracking using lever action)

- Row of holes to form a crack
- pneumatic breaker
- Rock cracked and split
Toe of slope strengthened by buttress wall
Various methods to stabilize a rock slope

- Reinforcing bars or mesh lapped to dowels bars
- Weepholes at intervals for intermittent seepage
- Filter layer formed of sandbags or graded filter
- Structural facing keyed or dowelled at base
- Longitudinal drain for steady seepage
- Weepholes
- Dowels
- Dentition
- Rock anchors
- Rock bolts
- Inclined drainhole
- Formation level
Improvement the slope profile by forming benches

Modified slope profile

Standard slope profile
Protecting a slope by the use of buttress wall
Rock anchor tying the exposed surface of slope with anchor head being covered for protection and future maintenance.
Protection and treatment to Earth-filled slope

Where a slope is to be stabilized to eliminate possible flow-slide, the surface layers should be stripped to a vertical depth not less than 3m and replaced it with dry and well compacted fill.

A drainage system is also required between old and re-compacted fill to prevent development of water pressure behind the filled zone.

If it is possible, try to reform the profile of the slope to a safe angle which is determined by mathematic analysis.
Slope without surface protection having the problem of erosion with the surface soil wash away by rain.
Signs of slope instability or heavy surface erosion.
Protection to slope by rigid surface

Rigid surface protection on slopes are commonly used to reduce rainwater infiltration and to prevent erosion of the slope-forming materials. This can be done by:

Chunam plastering – this is an applied-on surface protection to slope using a clay and cement mixed plaster. Thickness of the plaster is around 40mm to 50mm for permanent works.

Sprayed concrete (shotcrete) – protection by applying a spraying mortar onto surface of slope.

Masonry or stone pitching – lay stone rubble or block (with filter layer underneath) onto surface to protect slope from weathering

In general, rigid surface may create a very awkward appearance. Besides, the surface is highly impermeable thus weep holes are required for draining out of the ground water to avoid the development of high water pressure behind the slope
Top soil of slope surface without protection will easily be washed away.
Exposed rocks during slope cutting become unstable that require temporary or permanent protection.
巨石滚落山險擊中巴士

【本報訊】跑馬地發生巴士險被大石擊中意外。一塊有如籃球大的石塊，昨晨在山坡突滾下馬路，一輛巴士剛途經，幸司機及時煞車，避過被大石撞中巴士釀意外，警員到場將石塊移到路旁，待有關部門處理。

車長急煞避一劫

昨晨八時許，一輛雙層巴士沿大坑道落斜擬往北角碼頭，途至一一三號對開時，路旁山坡上一塊直徑逾一呎石塊突然鬆脫，從五米高山坡跌下，並滾出馬路。巴士車長驚見大石滾出，急忙煞車，大石在巴士車頭滾過，車長擔心再有石塊滾下，隨時擊中路過車輛及路旁巴士站候車乘客，立即報警求助。

警員接報到場，將石塊搬到行人路上，交通亦恢復正常。警方相信因泥土鬆脫，令石塊滾下，稍後將聯絡相關部門進行檢查。

石塊由山坡滾下險擊中途經巴士。 （梁卓明攝）
Preparing the surface of slope during maintenance process.
Forming a slope by scaling, cutting back into benches, and protect surface by rock nail and shotcrete.
Spraying concrete by compress air and nozzle

Spray concrete sometimes used as temporary protection for cutting slope
Spraying concrete by compress air and nozzle
Slope rock will be scaled off, covered with wire mesh and spray on with shotcrete as final protection. Subsoil drain (weep hole) to be provided where necessary.
Protection to slope by rigid surface (continue)

Masonry or stone pitching – lay stone rubble or block (with filter layer underneath) onto surface to protect slope from weathering.

In general, rigid surface may create a very awkward appearance. Besides, the surface is highly permeable thus weep holes are required for draining out of the ground water to avoid the development of high water pressure behind the slope.

Using stone pitching as a rigid slope surface
Improvement to slope by soft surface

After the preliminary protection treatment, slope can be further improved by some softer means, such as:

1. **Hydroseeding** – is the application of grass seed mixed with fertiliser and Nutriant in aqueous solution by spraying method. The grass seed will grow eventually and the root of the grass will act as an organic reinforcing fiber and hold the surface soil.

2. **Turfing** – Turfing is the direct application of grass with developed roots onto the slope surface. The relatively matured grass will grow easier and extend its root into the soil to strengthen the overall surface.

3. **Planting of tree** – usually done at the same time with the other method to provide better visual result and provide further strengthening effect to the slope by its deep root.
Various methods to treat a slope surface using vegetation.
Turfing a slope surface

Nylon mesh for sub-surface drainage and to reinforce the root of grass
Detail using addition erosion control mat and wire mesh to improve hard-spray slope surface.

- Galvanized and PVC coated wire mesh
- Erosion control mat
- Soil/Mulch mix. of greening technique
- Existing sprayed concrete
- Steel plate
- Fixing pins of minimum 12 mm diameter and minimum 300 mm length at 500 mm c/c
Stage of greening a newly treated slope

3rd month

4th month
Seeing the difference between a slope treated with and without landscaping provision
Protect a slope by the use of retaining wall

Retaining wall are structures usually provided at the toe of a slope to stabilize it from slide, overturn or collapse.

A slope will be relatively stable when its profile (section angle) is kept below its angle of repose.

Angle of repose is an angle that maintains naturally to a safe equilibrium by the composing material of a slope. This angle deviates from differing materials depending on their compaction, particle size and the nature of the material itself. (e.g. cohesiveness and shear strength)

Principle to retaining wall design can be of 2 main types

- cantilever type
- Gravity type
- Earth reinforced type
Various forms of RC cantilever type retaining wall structures.

(a) L-shaped Cantilever Retaining Wall

(b) Inverted T-shaped Cantilever Retaining Wall

(c) Reversed L-shaped Cantilever Retaining Wall with Key

(d) Inverted T-shaped Cantilever Retaining Wall with Key

(e) Retaining Wall with Counterforts

(f) Retaining Wall with Buttresses
Common failure modes of a retaining wall:

(a) Loss of Overall Stability

(b) Sliding Failure

(c) Overturning Failure

(d) Bearing Capacity Failure
Construction of typical gravity type retaining wall and its drainage arrangement

(a) Preferred Drainage Scheme A

(b) Preferred Drainage Scheme B

(c) Drainage Scheme C
Construction of typical cantilever type retaining wall and its drainage arrangement.

(a) Preferred Drainage Scheme A

(b) Drainage Scheme B
Stone mass at the toe of a bench serves to provide a gravity hold for the retaining soil-filled slope. Using stone pitching as a rigid slope surface.
Construction of RC cantilever/gravity mixed type retaining wall and finally formed a terrace to construct buildings.
Construction of Earth-reinforced retaining wall

Buttress of wall
Buttress of wall

Construction of Earth-reinforced retaining wall, with a temporary sheet-pile wall as stage one set-back arrangement.
Detail of the precast panel as surface panel of the retaining wall.
Detail seeing the tie behind the panel of the earth reinforced wall.
Other example of using earth reinforced wall to obtain extra space for a road widening project.
Examples where large-scale slope works are required in construction

1. Building work – obtaining of land space for building development by land/site formation

2. Roadwork – road or highway project including new projects, extension, widening or improvement works

3. Emergency/Major repair of slope, e.g. after serious land slide
Example of slope works for Building related project
Site formation to obtain a terraced land for the placing of a building—producing a retaining structure to support an adjacent structure.
Sequence showing the forming of a multi-construction retaining wall using bored-pile and soldier-pile wall with in-situ concrete facing wall.
Sequence showing the forming of a multi-construction retaining wall using bored-pile and soldier-pile wall with in-situ concrete facing wall.
Forming of a temporary vertical cut as part of the site formation work to acquire land for building construction project – Festival Walk

Diaphragm wall panel tie back using ground anchor
Site formation producing a temporary slope as part of a building construction component – CityU Academic Exchange Centre
Site formation producing a temporary slope as part of a building construction component – South China Sport Association Extension
Site formation producing a temporary slope as part of a building construction component – South China Sport Association Extension
Tree under preservation by encasing with a concrete trough and supported using horizontal steel pipes
The preserved tree grow in healthy condition along the re-aligned road side.
Setting back and stabilizing of a natural slope using buttress wall for a residential development project in Repulse Bay, Hong Kong.
Example of slope works for large-scale site formation or other Civil Engineering related projects
Slope stabilization to form a new coastal roadway near Cyberport.
Completion of the new roadway with the treated slope on the side heading toward Cyberport.

Buttress of wall.
Preliminary treated slope with geotextile underlay as support for growing plant or grasses.
Preliminary treated slope with geotextile and the growing of new grass afterward.
Main Carriageway

Made-slope treated with geo-textile and greening

Natural terrain
Widening of roadway by obtaining land cut to the edge of a building
Recovery of the road bend and the cut slope after widening with landscaping and pedestrian provision
Other examples of slope work or stabilization provision of more complex in nature—complicated topographic condition and work layout. Widening of Castle Peak Road near Sham Tseng.
Examples of some provisions to keep a slope safe from possible falling of loose materials by the use of catch fence.
Maintenance of slope

Conditions of a slope can be easily deteriorated within a certain period of time thus continual observation and maintenance should be carried out from time to time.

In Hong Kong, the responsibility of slope maintenance are:

- For lands belong to the government – by the government, responsible/managed by the Civil Engineering Department.

- For private lands – owner of the land. Very often the exact responsibility for the maintenance of a slope is specified in some legal documents such as in the land lease. Detail information for the lease documents and records of the land owners can be obtained at the Government’s Land Registry.
Maintenance Inspection (including slope and retaining walls)

Inspection should be carried out regularly to determine the conditions of a slope. These inspections can be sub-divided into 3 levels/categories.

1. Routine inspection – by non-professional person bases on some general visual guideline.

2. Engineer inspection – by qualified geotechnical engineer according to some engineering indications and standards

3. Regular monitoring process – by a quality engineering firm with special expertise and may involve the use of some monitoring devices or analysis
Routine Maintenance Inspection

As a preliminary inspection to ensure the basic stability of a slope, routine inspection is recommended to carry out on a regular basis. The following elements should be observed during the inspection:

1. Ensure the slope surface and its drainage channels are free from debris.
2. Damaged or cracked protective surfaces and drainage system should be repaired and kept in good condition.
3. Unblock the weep holes and drains from time to time.
4. Remove over-grown vegetation that may crack the surface.
5. Observe any damage appears on the slope or other retaining structures.
6. Observe any irregularity appears on or nearby the slope.
Common condition of a slope
Typical man-made items on slope and retaining wall that require maintenance.
Examples of poorly maintained slope

(1) Vegetated Surface

(2) Shotcreted Surface
Examples of poorly maintained slope

(3) Chunam Surface

(4) Masonry Facing
Examples of poorly maintained surface drainage
Examples of poorly maintained surface drainage
Figure 5.1  Typical Preventive Maintenance Works for Soil Slopes
Typical preventive maintenance works for rock slope stabilization:

- Improved surface drainage (U-channel at crest, toe or base)
- Improved surface protection - wire mesh
- Sliding rock block
- Rock dowel to stabilize rock block with a potential for sliding instability
- Surface stabilization measures e.g., scaling or dentition
- Relief drain
- Concrete buttress
- Discontinuity with seepage
- Rock trap ditch
<table>
<thead>
<tr>
<th>Item</th>
<th>Typical Maintenance Works Required</th>
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<tr>
<td>Surface Drainage Systems (e.g. drainage channels and catchpits)</td>
<td>(a) Clear debris, undesirable vegetation and other obstructions.  (b) Repair minor cracks with cement mortar or flexible sealing compound.  (c) Rebuild severely cracked channels.</td>
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<td>Weepholes and Surface Drainage Pipes</td>
<td>(a) Clear obstructions (e.g. weeds and debris) in weepholes and pipe ends.  (b) Probe with rods for deeper obstructions.</td>
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<tr>
<td>Rigid Surface Cover (e.g. chunam and shotcrete)</td>
<td>(a) Remove undesirable vegetation growth.  (b) Repair cracks or spalling.  (c) Regrade and repair eroded areas.  (d) Replace surface cover which has separated from underlying soil.</td>
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<tr>
<td>Vegetation Surface Cover</td>
<td>(a) Regrade eroded areas with compacted soil followed by replanting.  (b) Replant vegetation in areas where the vegetated surfacing has died.</td>
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<tr>
<td>Rock Slopes and Boulders</td>
<td>(a) Remove undesirable vegetation growth.  (b) Seal up open joints or provide local surfacing to prevent ingress of water.  (c) Remove loose rock debris.</td>
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<tr>
<td>Structural Facings</td>
<td>(a) Re-point deteriorated mortar joints on masonry face.  (b) Repair cracking or spalling of concrete surface and replace missing or deteriorated joint fillers and sealants.</td>
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**Typical Routine Maintenance Works for slopes and retaining walls**
Check List for Slope/Landslide Inspections

The site check list below may be used as a guide for landslide inspections during emergency, but it is by no means exhaustive. It includes the possible sources of danger and causes of failure which should be noted by the engineer in the course of his inspection.

(a) As water is normally the key element in triggering landslides, consider and look for the sources of water that are likely to adversely affect the situation and obtain the related information:

(i) rainfall and the time of failure (for correlation with development of rainfall at the nearest raingauge),

(ii) flooding and its timing,

(iii) concentrated surface water flow, channelised flow or areas of water ponding above the slope or along the road,

(iv) sewers and stormwater channels and drains, gullies, catchpits, cross road drains, etc., and their conditions,

(v) buried or exposed fresh or salt water pipes along the road and their conditions,

(vi) prominent water courses such as nullahs, natural drainage lines, etc., and their conditions, and

(vii) diversion of flow due to blockage of natural drainage lines and seepages from slopes.

(b) Look for indications of ground movement such as displacement and/or cracking of:

(i) paved ground, road kerbs and drainage channels,

(ii) slope drainage channels, catchpits, and

(iii) trees or other normally vertical features.

(c) Look at surface features for signs of distress:

(i) tension cracks on the ground surface or road pavement,

(ii) bulging of slopes or heave of ground or road,

(iii) local depression of paved ground or road,
(iv) subsidence of ground or road,
(v) excessive water seepage (indicative of high groundwater level or distressed services),
(vi) landslide debris, and
(vii) scouring or undercutting of the slope face, ground or road features by surface water.

(d) Check retaining walls including masonry type walls:

(i) tilt and horizontal misalignment,
(ii) settlement and undermining of foundations,
(iii) cracking (including broken tell-tales),
(iv) bulging,
(v) fallen debris or dislodgement of masonry blocks, and
(vi) excessive seepage and/or weephole flows.

(e) Look for other adverse features in the area where further deterioration may cause collapse:

(i) boulders/corestones (inadequate embedment),
(ii) open-jointed soil/rock faces,
(iii) leaning trees,
(iv) blocked slope or road drains,
(v) damaged slope surface protection,
(vi) pre-existing tension cracks,
(vii) old drainage lines,
(viii) recent changes to upslope or downslope environment (e.g. any resurfacing, demolition, site formation, utility installation, etc.) which could adversely affect the drainage characteristics of the area around the slope and road, and
(ix) material that has moved or been disturbed during the present landslide but has not yet detached from the slope.