ENGINEERING GEOLOGY AND ROCK MECHANICS

SKAA 2712
WEATHERING

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Introduction

- A tropical country has sunny flux all year round (22^0-32^0C), high moisture content in the air and underground, high quantity of rain (>1200 mm) and underground water temperature of 28^0C (Thomas et al., 1992).
- With these characteristics, climate has a great influence to exogenic process especially to chemical weathering process where the high intensity of rain and high temperature will accelerate the weathering process.

Introduction

- Weathering of rock takes place under the influence of the hydrosphere and atmosphere.
- Weathering can be either in the form of mechanical disintegration or chemical decomposition or both.
- Mechanical weathering leads to opening of discontinuities by rock fracture, opening of grain boundaries and the fracture on cleavage of individual mineral grains, whereas chemical weathering results in chemical changes in the mineral.
- Under the influence of weathering, the strength, density and volumetric stability of the rock will be reduced, whilst deformability, porosity and weatherability are increased.
- This can lead to significant reductions in rock strength process

Introduction

- Mechanical weathering – physical forces break earth materials into smaller pieces that retain the composition of the parent material.

- Chemical weathering – involved a chemical transformation of rock into one or more new compound.

Mechanical weathering

1. **Frost wedging**

- **Repeated cycles of freezing and thawing.**
- **Liquid water expand 9% when it freezes → increase in volume.**
- **Rock broken into angular fragment.**
- **Cause destruction in highway (US & Canada).**

2. Unloading.

- When large mass of igneous rock exposed by erosion – concentric slabs begin to break loose.
- Sheeting – process generating onionlike layers.
- Outer layer expand more than rock below → separate from the rock body.
- Create exfoliation dome – Yosemite N.P.
- E.g. deep underground mining – removal of confining pressure.

3. Thermal expansion.

- Volume of rocks changes as they heat up (extraction) & cool down (contraction).
- Surface expansion generate stress to cause fracturing.
- Dark minerals absorbs heat faster than light minerals – diff. expansion between minerals.

4. Biological activity.

- **Involve both mechanical & chemical weathering.**
- **Plant roots search for minerals & water grow into fractures → wedge the rock apart.**
- **Then, root & fungi that occupy fractures or encrust the rock produce acids → decomposition.**

Chemical weathering (Decomposing of Rocks)

- **Water is most important agent of chemical weathering.**
- **Pure water : nonreactive → + dissolved material (oxygen will oxidize some materials, e.g. iron).**

Chemical weathering

- **Dissolution – ionic bonds between ions are broken and the separated ions are carried away in water**
- **$H_20 + CO_2 \rightarrow H_2CO_3$**
- **$CaCO_3 + H2CO_3 \rightarrow Ca^{2+} + 2HCO_3$**
- **Oxidation –a positive ions combine with oxygen to form oxide.**
- **Hydrolysis – (H^+) & (OH^-) from water molecules displace other ions from a mineral structure, forming a different mineral.**

Weathering Profile in Basalt

Photo taken by Edy Tonnizam May 2010

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Photo taken by Edy Tonnizam May 2010

Photo taken by Edy Tonnizam May 2010

Residual Soil of Granite

Photo taken by Edy Tonnizam May 2010

Photo taken by Edy Tonnizam May 2010

Mamut Copper Mine, Sabah

Factors That Influence Chemical Weathering

- **Amount of mechanical weathering.**
- **Mineral structure and composition**
- **Jointing.**
- **Climate**
- **Wet > dry, Heat > Cool**
- **Time**

Some Product of Chemical Weathering

- **Clay Minerals**
- **Metal Ores**
- **Boulders**

Karst Landscape

Photo taken by Edy Tonnizam May 2010

Photo taken by Edy Tonnizam May 2010

Soil Formation

- **Parent Material**
- **Positive ion – lava- potassium, magnesium and calcium**
- **Climate**
- **Topography**
- **Biological Activity**
- **Time**

Weathering profile

- **Study on weathering process and local climate is very important to find out whether failure is caused by the weakness of material or the discontinuities of rock mass.**
- **Weathering is subjective – little information – difficult to be included in design**
- **Degree of weathering of rock is evaluated by site assessment.**

  - Rock mass : Zone 1 – Zone 6

  - Rock material : Grade I – Grade VI

Weathering profile

- **The study of weathering profile is still in early stage in Malaysia and the need to understand the behaviour of this weathered rock is vital as majority of construction works are in these zones (Ibrahim Komoo, 1995).**
- **Depending on the mineral composition and types of rock, chemical weathering also forms variable weathering profiles that is clear to igneous, metamorphosed, and sediment rocks**

Weathering profile

- Sandstone behaves differently as compared to shale to weathering agents because of their genesis. Fresh sandstone, which is well cemented, has minimal foliation and lamination as compared to shale and relatively difficult to break (Edy Tonnizam et al. 2011b).
- Shale is always known to have laminations, which provides spaces for weathering agents to be in contact. Furthermore, shale is composed of clay-sized material that is smaller than 0.062mm in size and some of clay types such as illite and montmorillonite may absorb water aggressively and will degrade easily on exposure to weathering agents when compared to sandstone.

In igneous origins area, we can expect an abundance of boulders, which may have similar strength, but vary in size.

Photo taken by Edy Tonnizam May 2006

Description of the weathering grade (after Attewell, 1993)

Degree of Weathering	Descriptive terms	Material description and likely engineering characteristics
VI	Residual soil	Completely degraded to a soil; original rock fabric is completely absent; exhibit large volume change; the soil has not been significantly transported. Stability on slopes relies upon vegetation rooting and substantial erosion & local failures if preventive measures are not taken
V	Completely weathered	Rock is substantially discolored and has broken down to a soil but with original fabric (mineral arrangement & relict joints) still intact; the soil properties depend on the composition of the parent rock. Can be excavated by hand or ripped relatively easily. Not suitable as foundation for large structures. May be unstable in steep cuttings and exposes surfaces will require erosion protection.
IV	Highly weathered	Rock is substantially discolored and more than 50% of the material is in degraded soil condition; the original fabric near to the discontinuity surfaces have been altered to a greater depth; a deeply weathered, originally strong rock, may show evidence of fresh rock as a discontinuous framework or as corestone; an originally weak rock will have been substantially altered, with perhaps small relict blocks but little evidence of the original structure. Likely engineering characteristics are as in Zone 5.
III	Moderately weathered	Rock is significantly discolored; discontinuities will tend to be opened by weathering process and discoloration have penetrated inwards from the discontinuity surfaces;
II	Slightly weathered	Some discoloration on and adjacent to discontinuity surfaces; discolored rock is not significantly weaker than undiscolored fresh rock; weak (soft) parent rock may show penetration of discoloration. Normally requires blasting or cutting for excavation; suitable as a foundation rock but with open jointing will tend to be very permeable.
I	Fresh	No visible sign of rock material weathering; no internal discoloration or disintegration. Normally requires blasting or cutting for excavation; may require minimal reinforcement in cut slope unless rock mass is closely jointed.

Weathering profile

- **Weathering – affects the strength of rock.**

- **Weathering profile is important as to account for the engineering properties (strength, porosity etc.).**

- **Effect the construction work:**

- **Slope angle.**
- **Type of foundation & structure.**
- **Method of excavation (excavate, ripping, blasting)**
- **Method of stabilization.**
- **Depth of pile (Grade I & Grade II).**

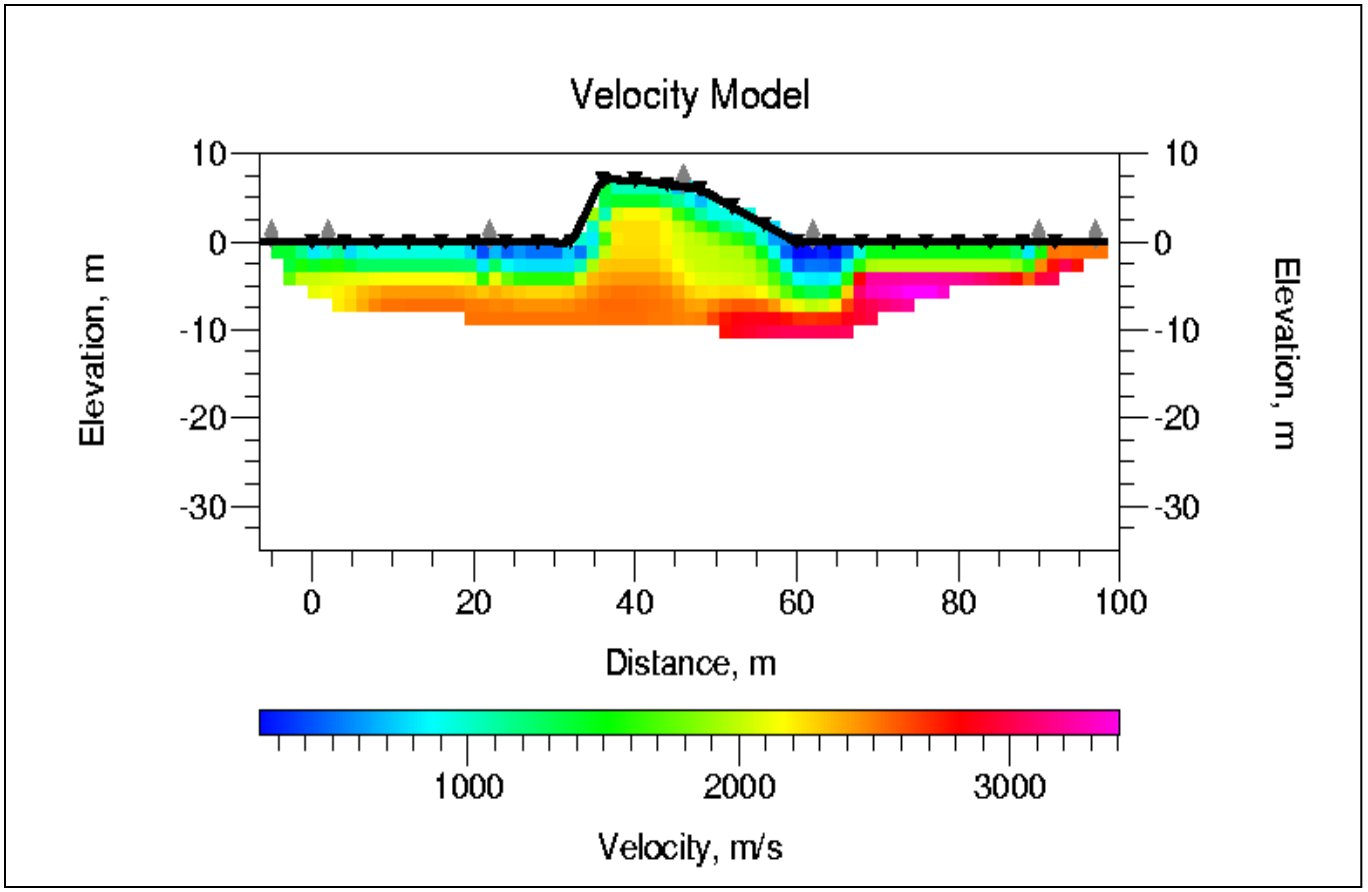
Old alluvium

Photo taken by Edy Tonnizam May 2006

Crocker Formation, Sabah

Photo taken by Edy Tonnizam May 2009

Seismic velocity survey



GRANITIC/ SEDIMENTARY WEATHERING PROFILE

- Granitic – occurrence abundance of boulders, sharp boundary between weathering grades might be observed (Edy Tonnizam et al., 2011a)
- Sedimentary- consist more than one type of material, structurally affected by tectonic activity, various weathering grade depending on the rock type.

GRANITIC/ SEDIMENTARY WEATHERING PROFILE

- The granite rock formations do not consist of uniformed boundaries and layers (Edy Tonnizam et al. 2011a).
- It was observed that the formation layers varied significantly within a small area, in terms of mineral composition, extent of weathering, rock texture and other features.
- This proves the fact that the characteristics of the rock's vertical profile are not identical to adjacent areas, even though just a short distance away.

- Rocks with coarser textures are actually weaker in terms of strength in comparison with fine textured rocks.
- This was proven when observing that the former could be easily broken by hand or geological hammer.
- The outer surface of the rock formation and areas along the joints were observed to consist of a coarser texture.
- Apart from that, this also indicates that fine textured rocks have greater strength due to strong interlocking and bonding between the particles.

- As reported by Ibrahim Komoo (1995), chemical weathering in tropical areas has resulted in a thick weathering profile with abundant of boulders to be expected in granitic areas.
- Granite boulders have higher strength when compared to the surrounding material.
- Generally, sedimentary rock mass consists of more than one type of rock and always forms alternate layer because of the natural forming process and are also exposed to tectonic effects and pressure.

Weathering profile in granite

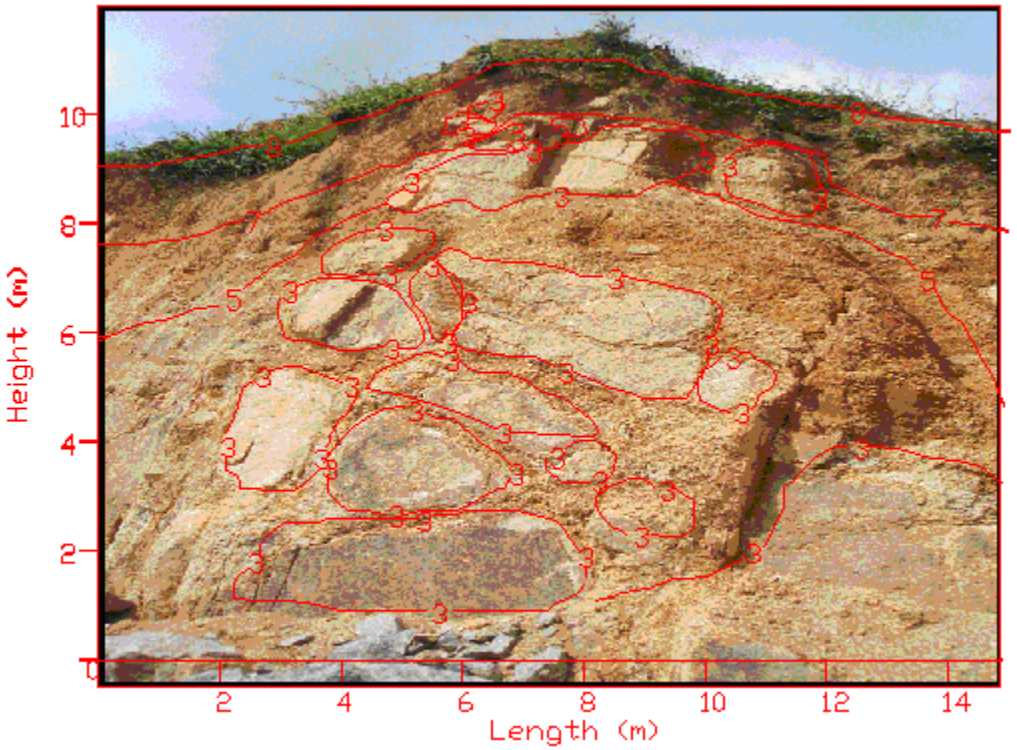


Photo taken by Edy Tonnizam May 2010

Inhomogeneity of weathering grades in sedimentary rocks

Photo taken by Edy Tonnizam May 2006

- In sedimentary rock, the occurrence of bedding, folding, foliation and inhomogeniety of rocks are few distinctive differences compared to igneous rock.
- Shale, which is inter-bedded with sandstone, would have lower in strength when compared to sandstone (Edy Tonnizam et al., 2011b).

Effect of Weathering in Kundasang, Sabah

Photo taken by Edy Tonnizam May 2006

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