Geotechnical Approaches for Sustainable and Resilient Architectural Design

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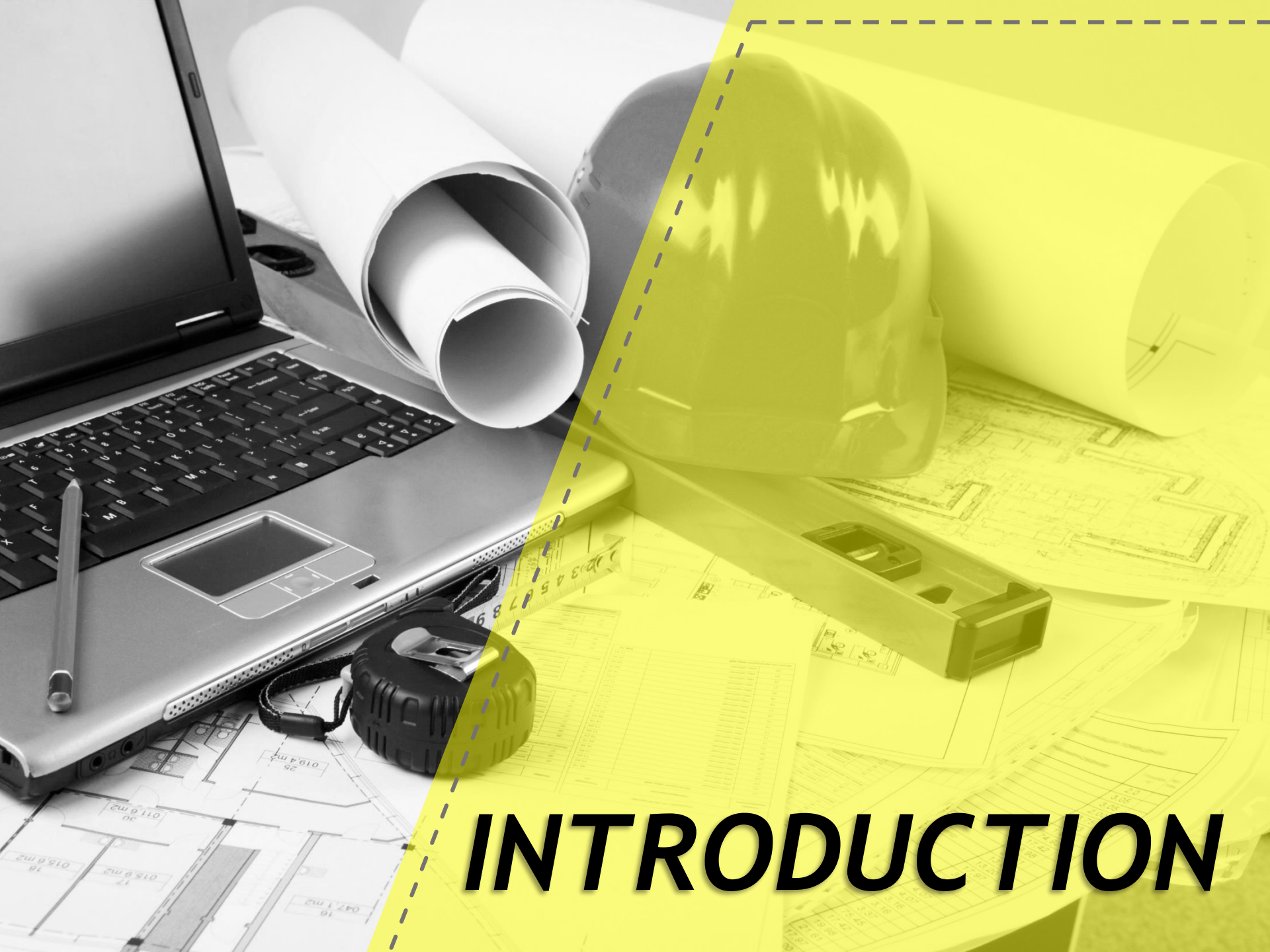

INTRODUCTION

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Traditional practices in which focus is only on the technical and financial aspects during the design and construction stages

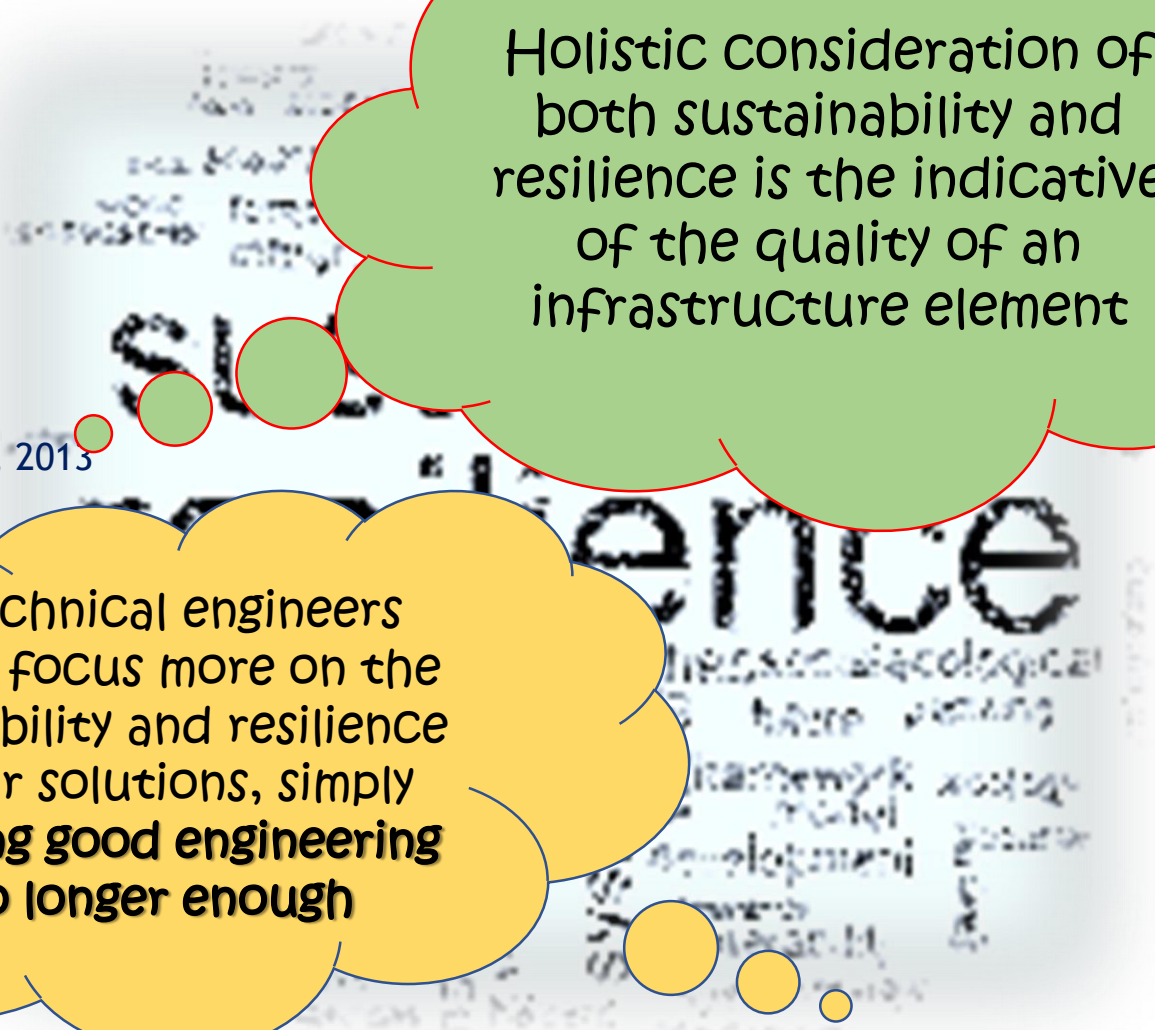
Holistic consideration of both sustainability and resilience in buildings and infrastructures development

INTRODUCTION

Holistic consideration of both sustainability and resilience is the indicative of the quality of an infrastructure element

Bocchini et al., 2013

Geotechnical engineers need to focus more on the sustainability and resilience of their solutions, simply **providing good engineering is no longer enough**



Jeffrey Keaton

INTRODUCTION

- Sustainability – **dynamic equilibrium** between four **E**s – engineering design, economy, environment and equity from a geotechnical perspective.

1 ENGINEERING DESIGN

2 ECONOMY

3 ENVIRONMENT

4 EQUITY FROM A GEOTECHNICAL PERSPECTIVE

- Resilience – ability to addresses the sudden impact due to unanticipated failure

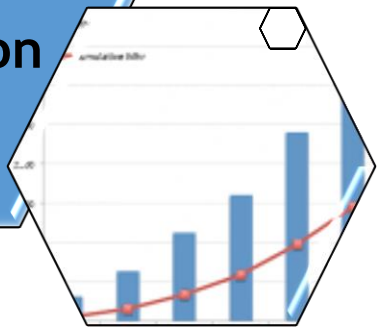
INTRODUCTION

- building project is basically architect-led with the technical expects entering the process after the major decisions have been made
- Some technical requirement and considerations are too often left out of the conceptual design proposals
- Lead to extensive design changes
  → significant time delay and cost overrun.
- If geotechnical requirements are being ignored or underestimated due to cost and time constrains and resulted in serious geotechnical problems arise during or after the construction.

INTRODUCTION

most resource intensive

early position in the construction cycle



- ✓ metric balancing environmental
- ✓ effectiveness technological feasibility
- ✓ economic profitability

IMPORTANT OF EARLY COLLABORATION

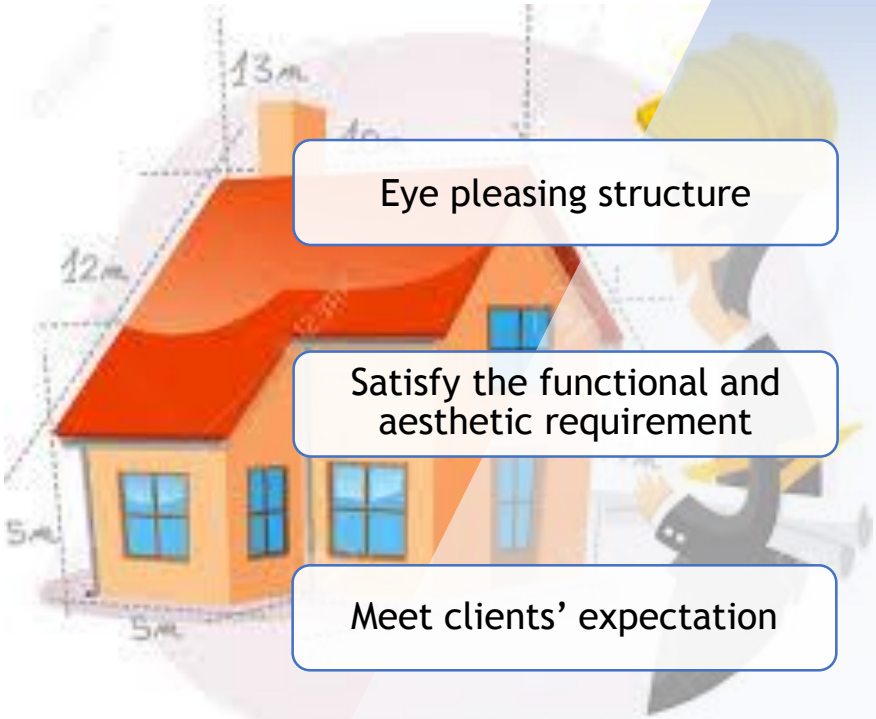
Gaining opinion, feedback and option of the design solution

Gathering the best engineering consideration

Working together - sharing information and knowledge

IMPORTANT OF EARLY COLLABORATION

set aside preconceived professional attitudes and encourage the cooperative lateral thinking and interdisciplinary engagement before the design, during and after the design process



Eye pleasing structure

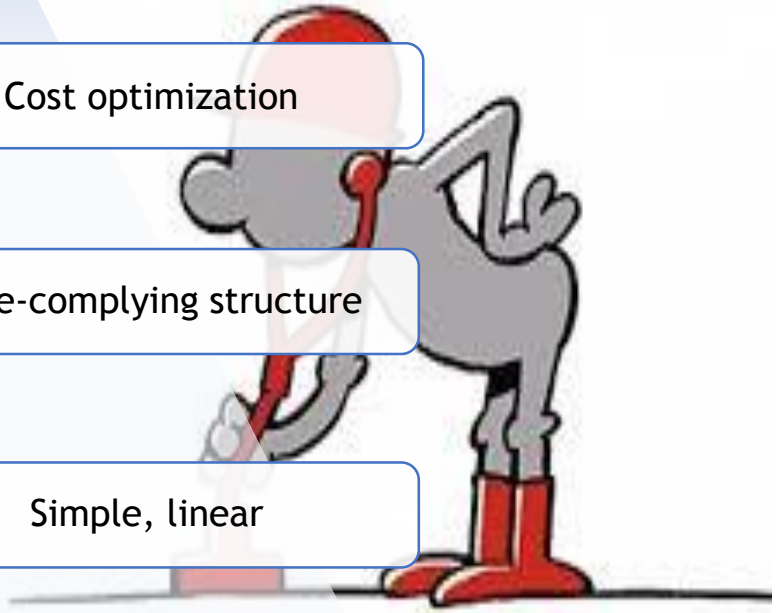
Satisfy the functional and aesthetic requirement

Meet clients' expectation

Cost optimization

Code-complying structure

Simple, linear



INTRODUCTION

- Early collaboration between the architect and other engineering partners including geotechnical engineer is essential to ensure the feasibility, viability, constructability, economy, efficiency and sustainability in the design proposal

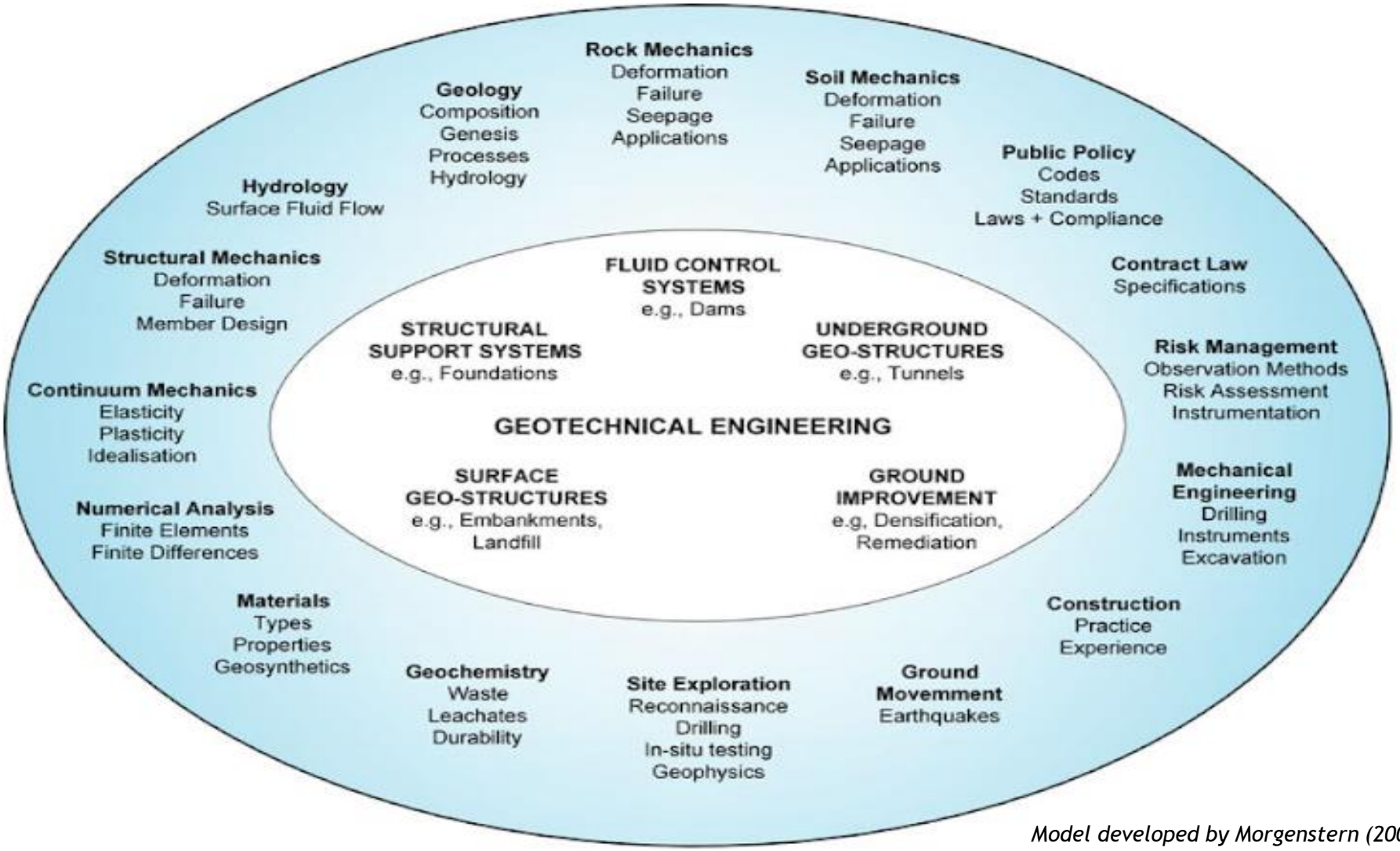
SCOPE OF GEOTECHNICAL WORKS

SCOPE OF GEOTECHNICAL WORKS

- Geotechnical works basically covers whatever that deal with **earth materials**.
- Geotechnical engineering uses principles of **soil mechanics** and **rock mechanics** to **investigate the subsurface conditions and materials**, to determine the relevant **engineering properties** of these materials for development.

SCOPE OF GEOTECHNICAL WORKS

Interactions of various disciplines that contribute to geotechnical engineering



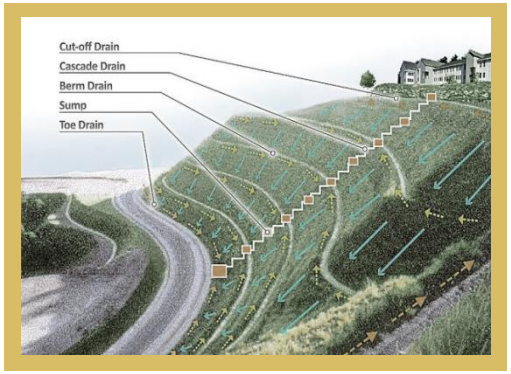
Model developed by Morgenstern (2000)

SCOPE OF GEOTECHNICAL WORKS

Some typical categories of geotechnical works are listed below:

1 SOIL INVESTIGATION

2 SLOPE OR SOIL STRUCTURE STABILITY

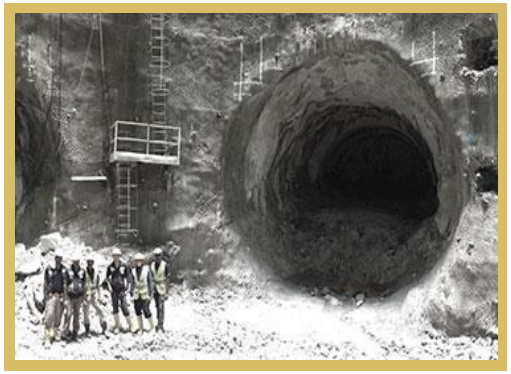


3 FOUNDATION

4 EARTHWORK, RETAINING STRUCTURES & DEEP EXCAVATION

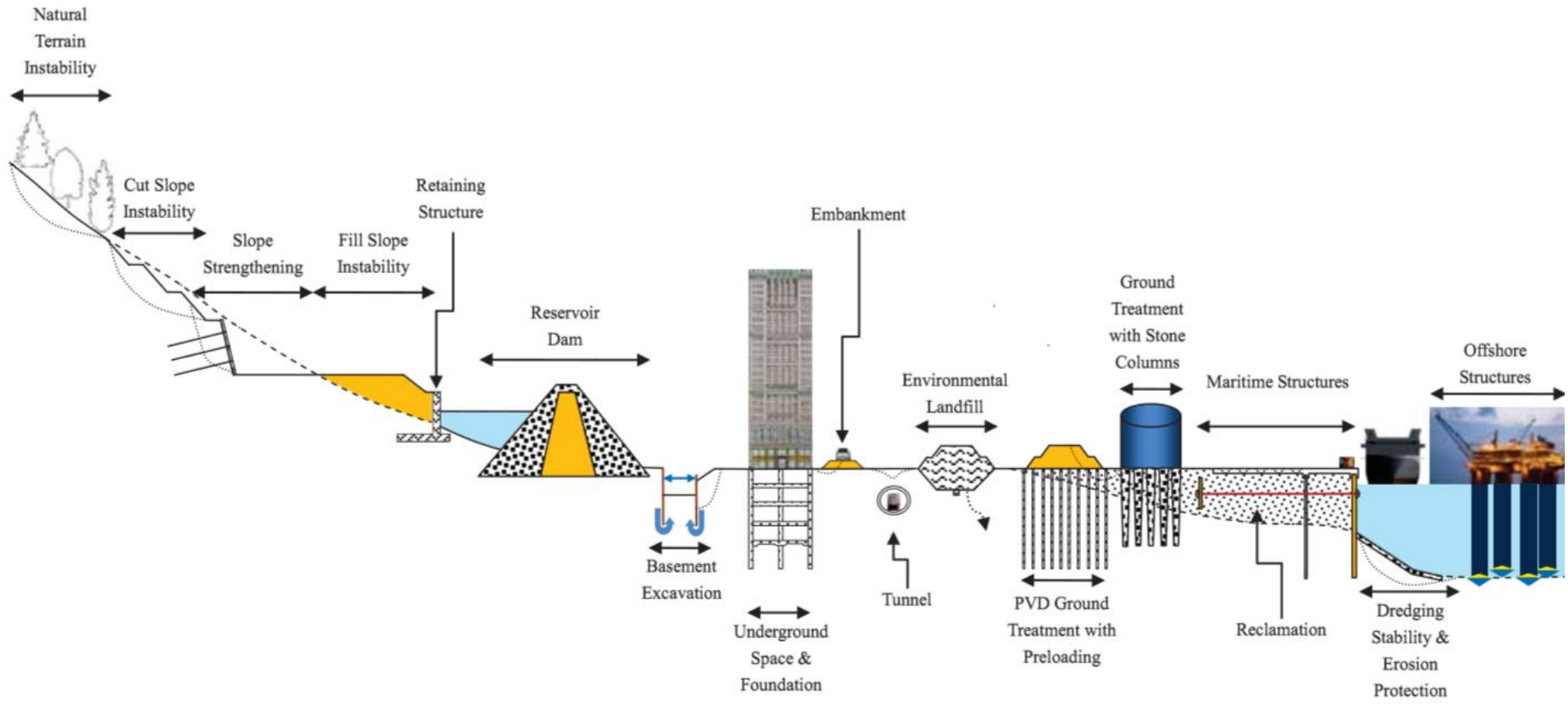
5 GROUND IMPROVEMENT AND LAND RECLAMATION

6 TUNNEL AND UNDERGROUND SPACE



SCOPE OF GEOTECHNICAL WORKS

The overview of potential scope of geotechnical engineering worldwide



GEOTECHNICAL WORKS

- UNIQUE
- STATE –OF –THE ART

SCOPE OF GEOTECHNICAL WORKS

In a building construction, designers can :

- select the material used to construct the structure;
- specifications can be nominated for these materials;
- the quality of the materials can be controlled during manufacture
- and the material properties can be validated and defined with real reasonable precision prior to use in the construction.

SCOPE OF GEOTECHNICAL WORKS

However, the situation is different in geotechnical engineering due to the following:

- materials are natural and not subjected to quality control during their ‘manufacture’;
- materials possess mechanical properties which are scale dependent in both space and time;
- often heterogeneous (not uniform in composition);
- usually anisotropic (having different properties in different directions);
- comprise discontinuous fractured media such as joints, bedding planes, faults etc and
- subjected to complex solid-fluid interaction.

APPLICATION OF GEOTECHNICAL ENGINEERING IN SUSTAINABLE & RESILIENCE DESIGN

Planning stage - **feasibility study** is a must

- In this stage, the geotechnical engineer needs to study all information pertaining to the project site and its surrounding including the **site topography, the subsoil condition** and **any geo-hazard risks** present within or surrounding the site.
- Adequate knowledge of subsoil condition is also very crucial hence it is good to have a preliminary soil investigation results during the site feasibility study stage.
- All this information may affect the design decision including suitability of the site, location of the buildings, cost required and time needed for the whole construction activities

Earthworks for Development in Hilly Terrain

One of the features in sustainability effort is the **BALANCED EARTHWORKS**

Minimise
Not Only
Balanced
The
Quantity Of
Cut And Fill

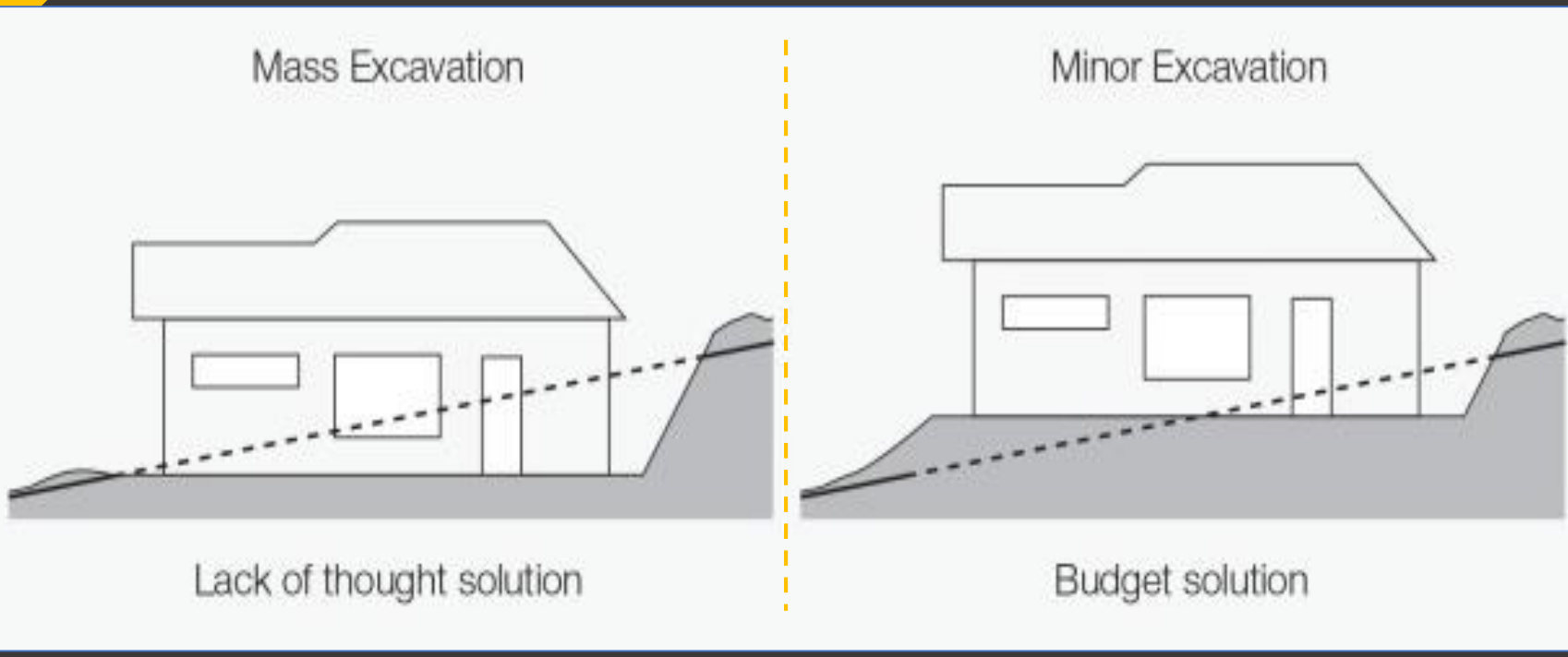
- reduced earthworks required
- saving time & project cost
- more **environmental friendly** by **saving fuel consumption** and **reducing carbon dioxide emission**

Example

The green construction of The Chicago O'Hare Airport Modernization Program which involved construction of new runway had reported saved over $180 million by reducing truck trips and fees for dumping at landfills. Resulting from balanced earthwork, saving in duel consumption and the reduction in CO_2 emission was 9.6 million gallons and over 97,000 tons respectively.

Earthworks for Development in Hilly Terrain

The common way an architect designing building platform :



Earthworks for Development in Hilly Terrain

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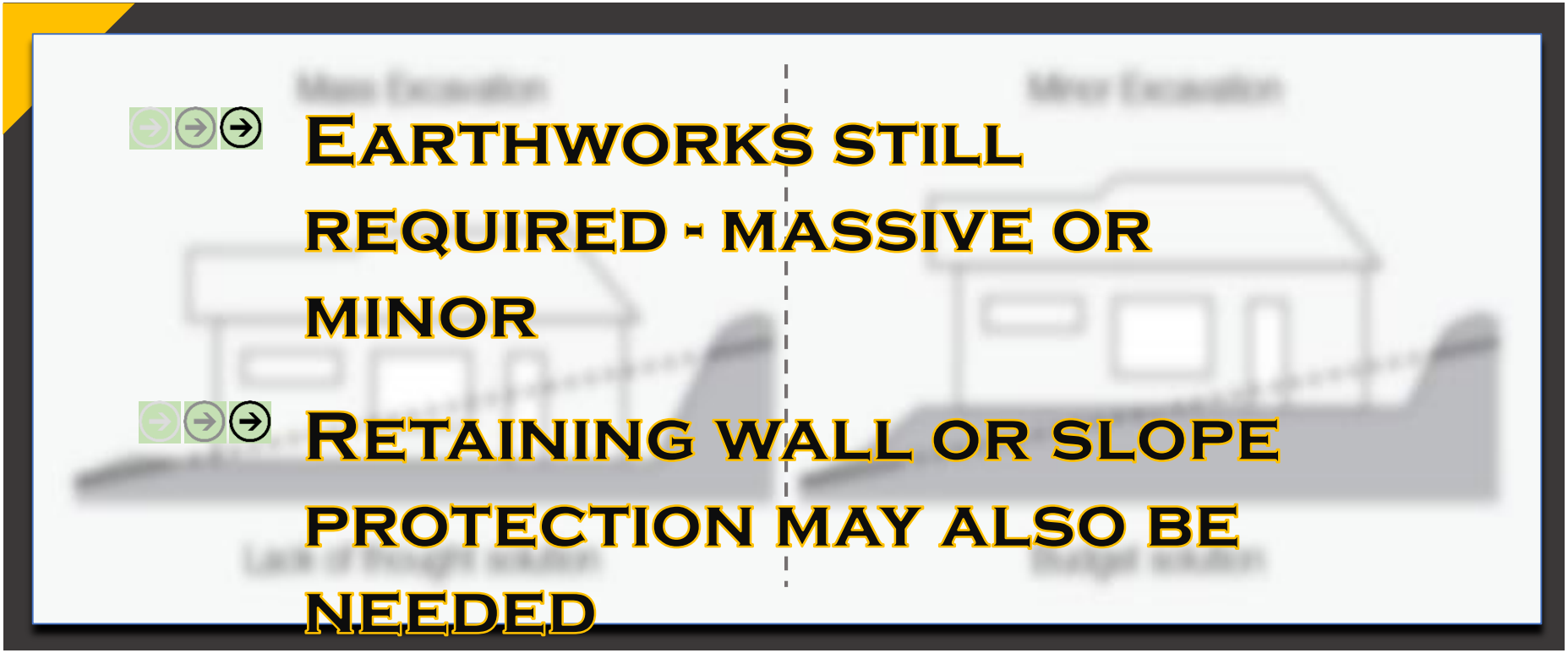
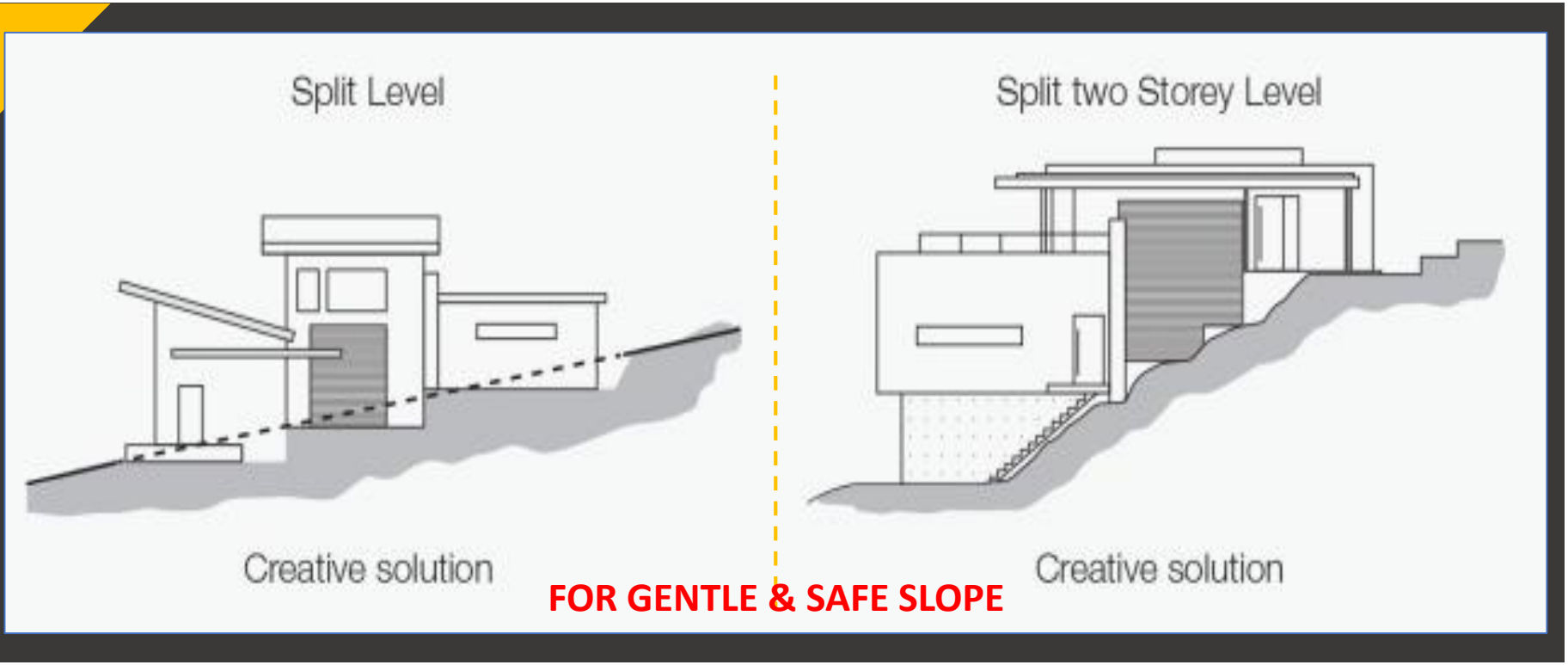


- Innovative solution consideration **sustainability**
  - building structure designed to suit the sloping ground level



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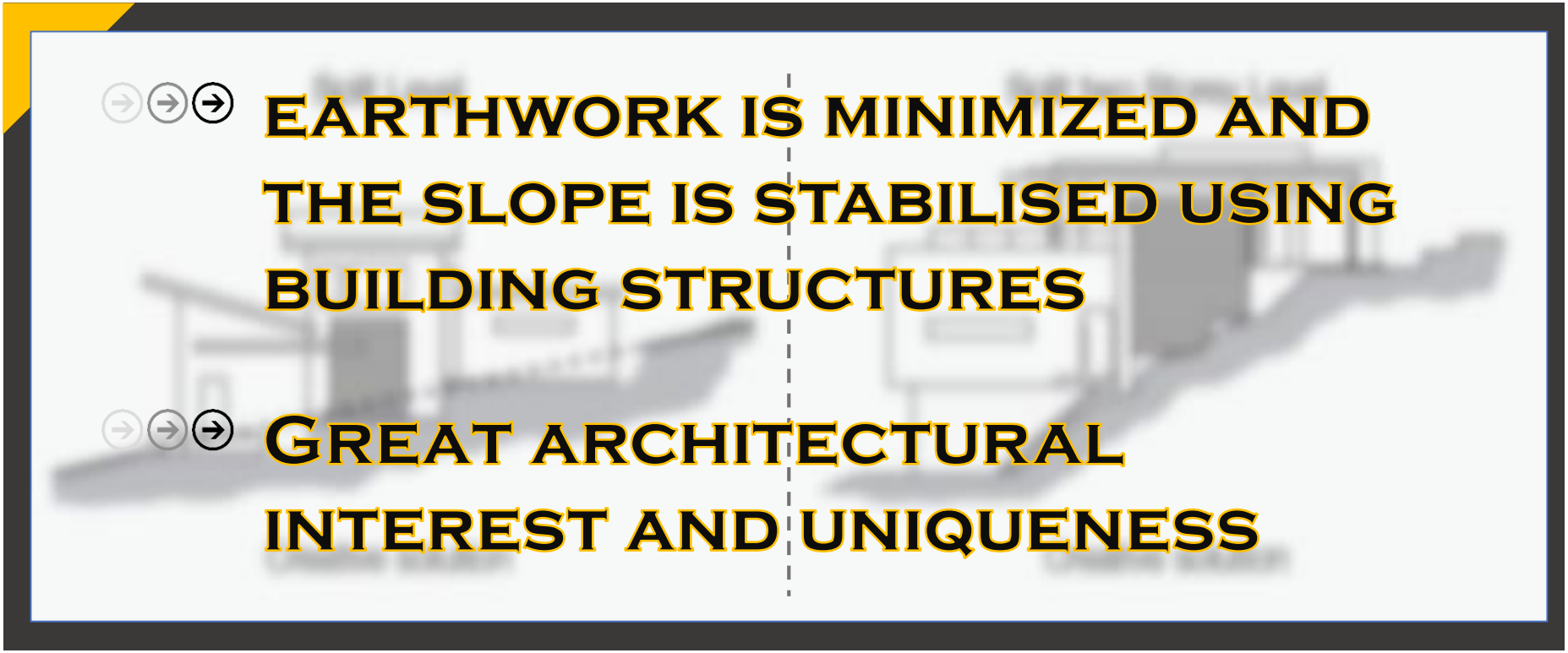
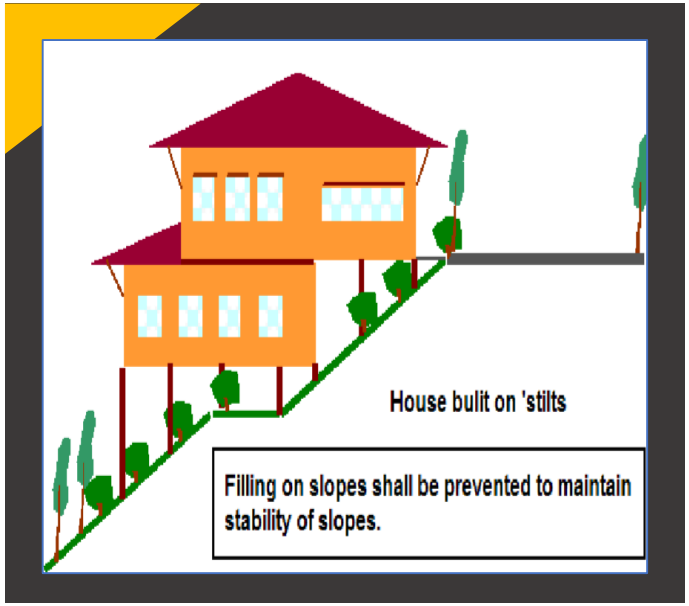


Earthworks for Development in Hilly Terrain

For high & steep slope

- building with extended columns
- to reduce the load impose on the slope

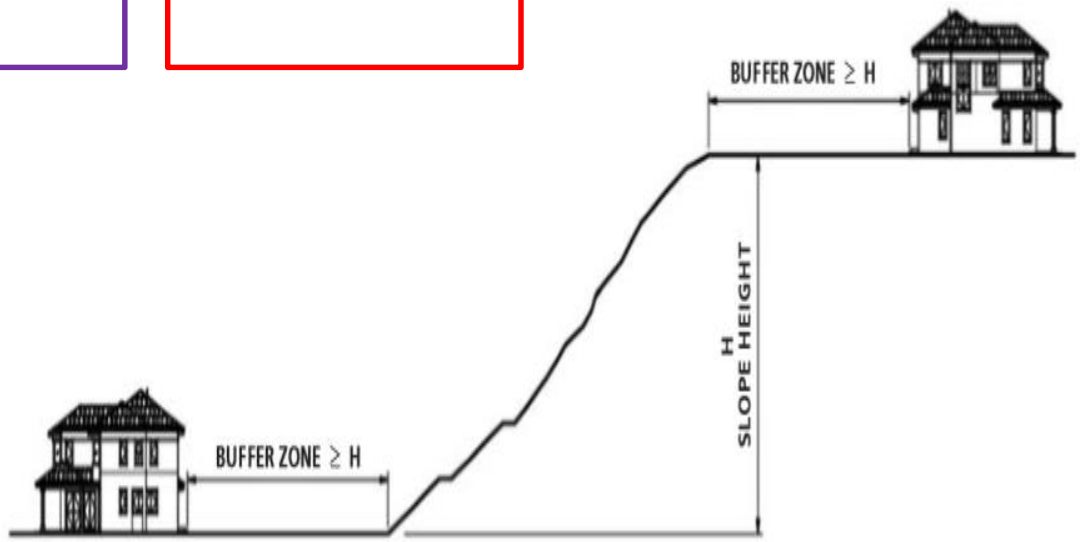


Earthworks for Development in Hilly Terrain

- Minimized differential settlement
  - Cut and fill ground

- Stability of the slope

- Safe & comfortable buffer for building



Ground Improvement for Soft and Compressible Ground

Ground Improvement for Soft and Compressible Ground

Problematic soil such as **soft clay** and **organic peat soil**

Large long term primary and secondary consolidation **settlement**

Stability issue

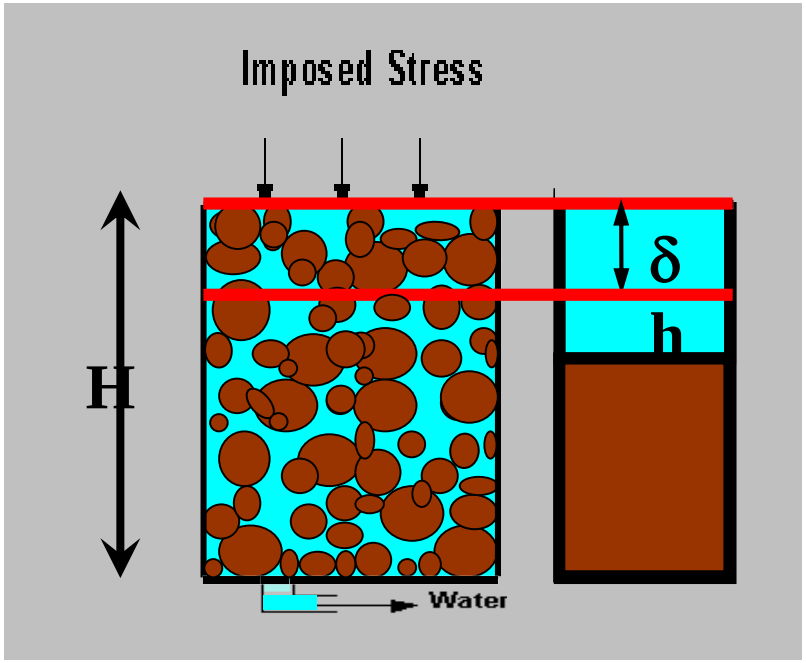
- ❑ **Building cracks & damaged**
- ❑ **Underground utilities malfunction**

Ground Improvement for Soft and Compressible Ground

some examples of the buildings affected by ground settlement in Malaysia.

Ground Improvement for Soft and Compressible Ground

- Sustainability and resilience cannot be achieved if the structures cannot withstand such a soil collapses or sudden excessive settlements, and remedial are needed to improve such situation.
- If the ground is investigate in detail before the development embark and sustainable and resilient solution is suggested together with the cost considered during the planning stage, it will definitely reduce the problem that arise later.
- Ground improvement method is one of the basic approaches to reduce the ground settlement problem in soft clay and peat soil area. There are various type of ground improvement method can be considered, from the most least cost but more time consuming to the fastest solution but high cost option.



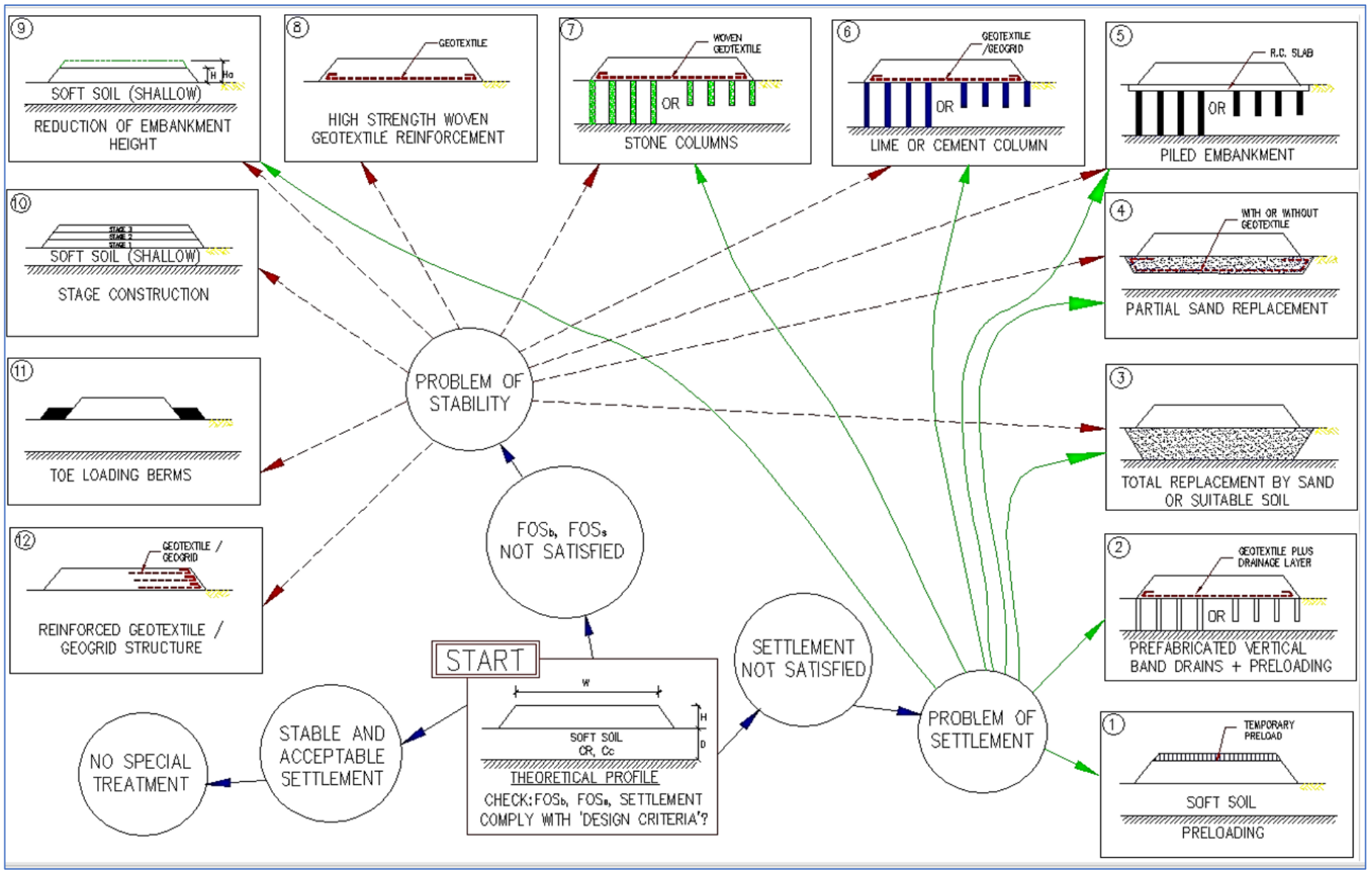
Drainage of **excess pore water pressure** Induced by increase in stress

Reduction in **volume**-saturated soil

Increase in **effective stress**

Ground consolidate & settle

APPLICATION OF GEOTECHNICAL ENGINEERING IN SUSTAINABLE & RESILIENCE DESIGN



Ground Improvement for Soft and Compressible Ground

Installation of pre-fabricated vertical drain

Ground Improvement for Soft and Compressible Ground

Installation of pre-fabricated vertical drain

Ground Improvement for Soft and Compressible Ground

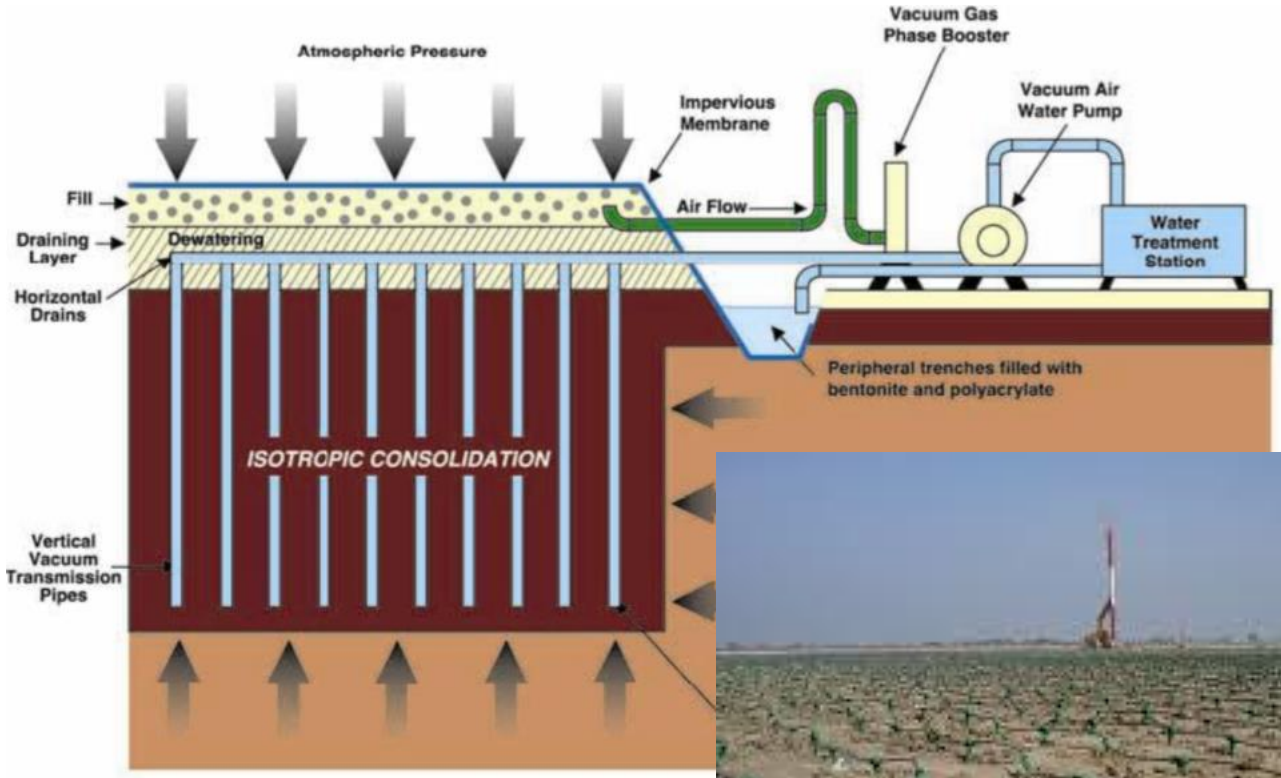
Stone column installation

Ground Improvement for Soft and Compressible Ground

Stone column installation

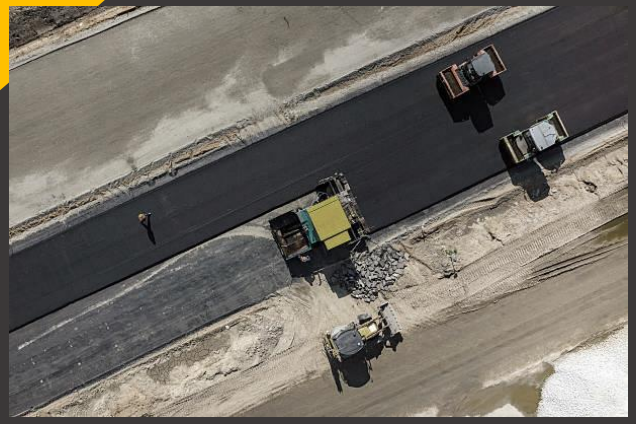
Ground Improvement for Soft and Compressible Ground

Vacuum consolidation using pre-fabricated vertical drain



Ground Improvement for Soft and Compressible Ground

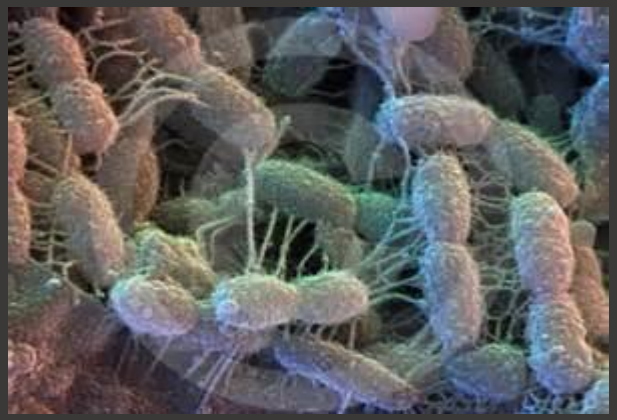
However, the cheapest and easiest solution will not always be the most environmental friendly solution.



According to the case study presented by Menard in 2011, for a project road construction over peat soil in Putrajaya, the original design was to carry out remove and replace of the peat soil up to 6m deep resulting in fuel consumption of approximate 1,412,800 litres which is equivalent to 3,815 tons of CO^2 emission.

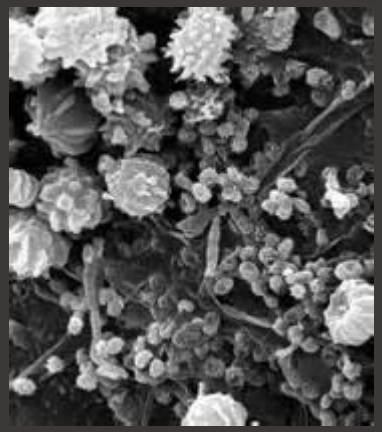
Alternatively a more sustainable solution was proposed by using in-situ replacement with granular material in the form of column by means of heavy impact to overcome the settlement problem and increase the ground bearing capacity. With this solution, the fuel consumption had been reduced to 201,950 litres and overall carbon footprint reduced by 3,270 tons.

Ground Improvement for Soft and Compressible Ground

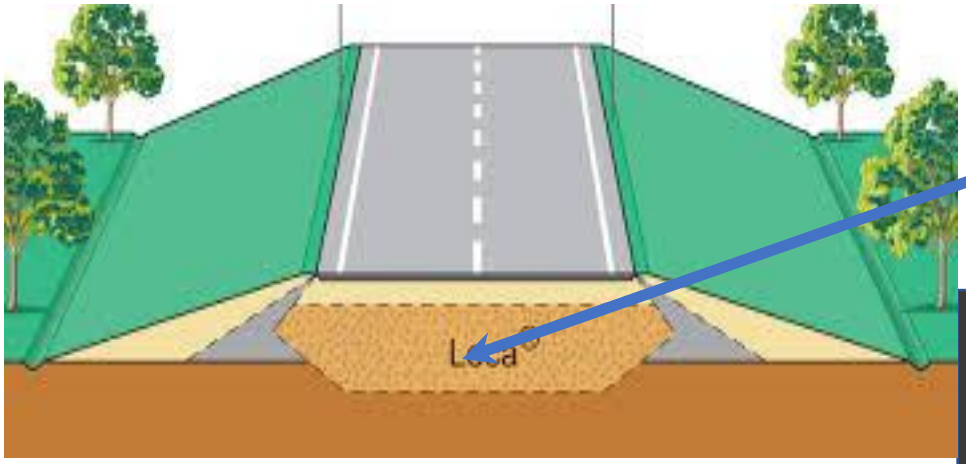


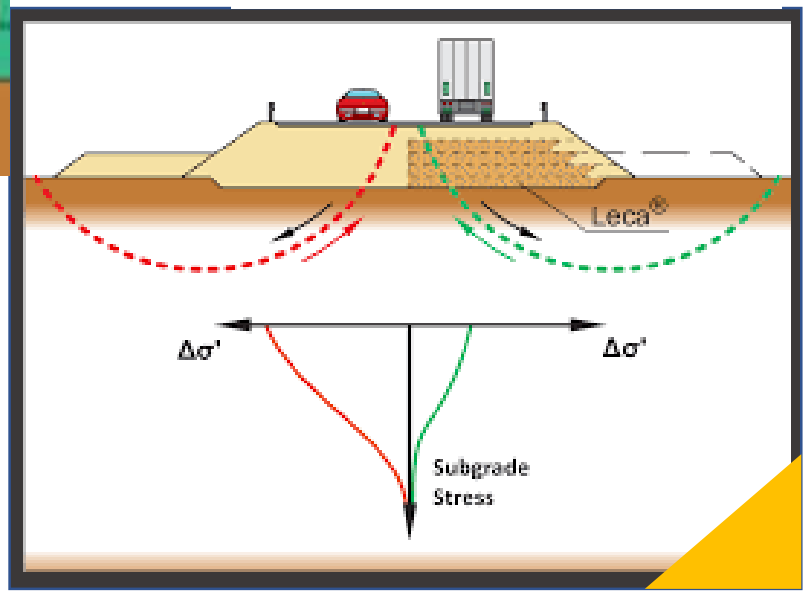
Innovative and environmental friendly solutions

- using of microbial geotechnology to improve the properties of peat soil and further reduce the soil compressible issue



Ground Improvement for Soft and Compressible Ground

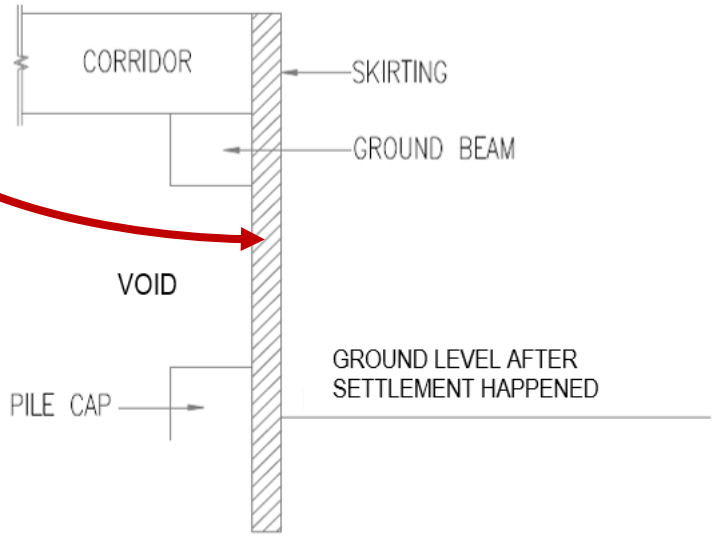




- Replacement of soil with lightweight material

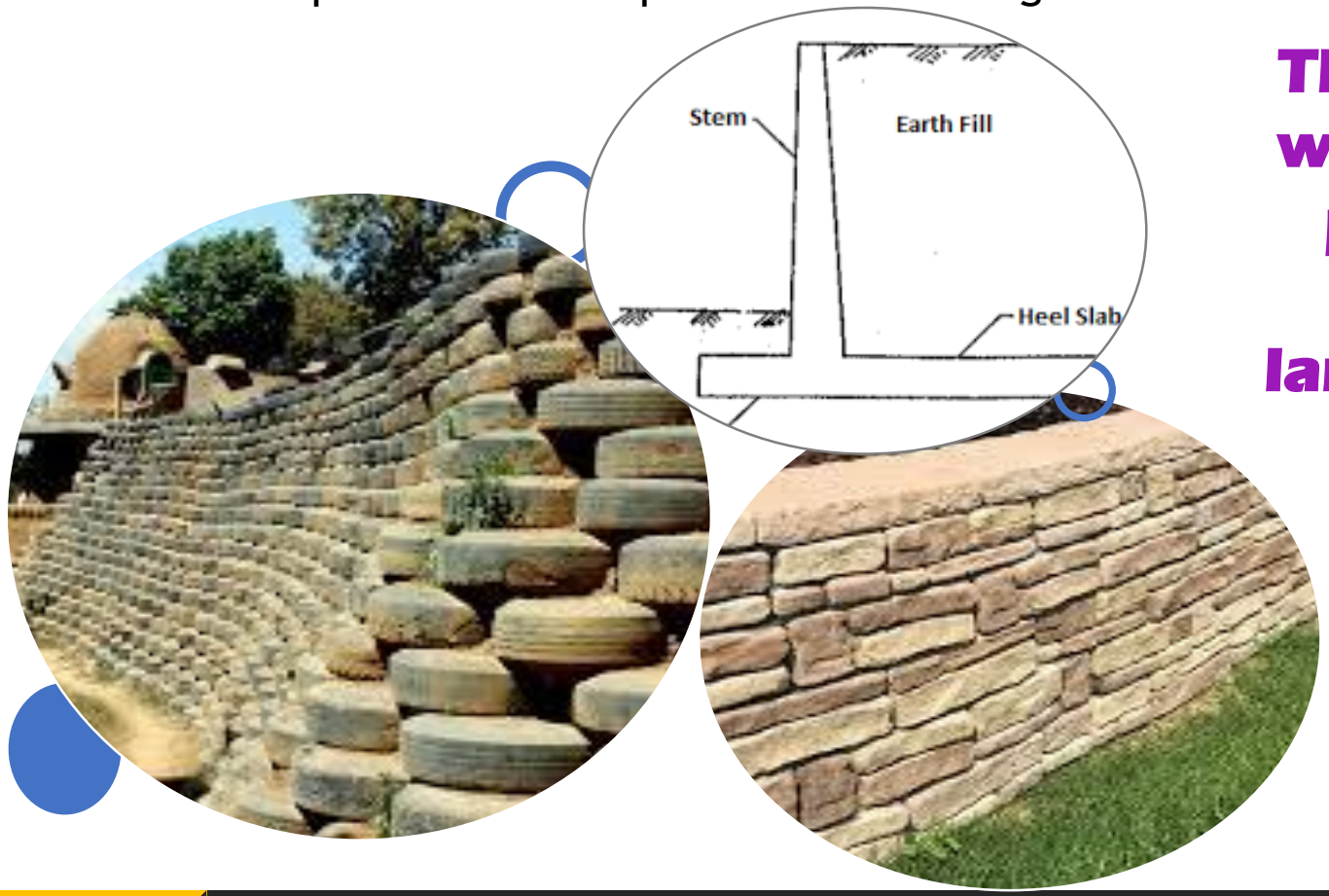
Ground Improvement for Soft and Compressible Ground

- Resilient solution for building susceptible to ground settlement



Environmental Green Slope Protection System and Retaining Wall

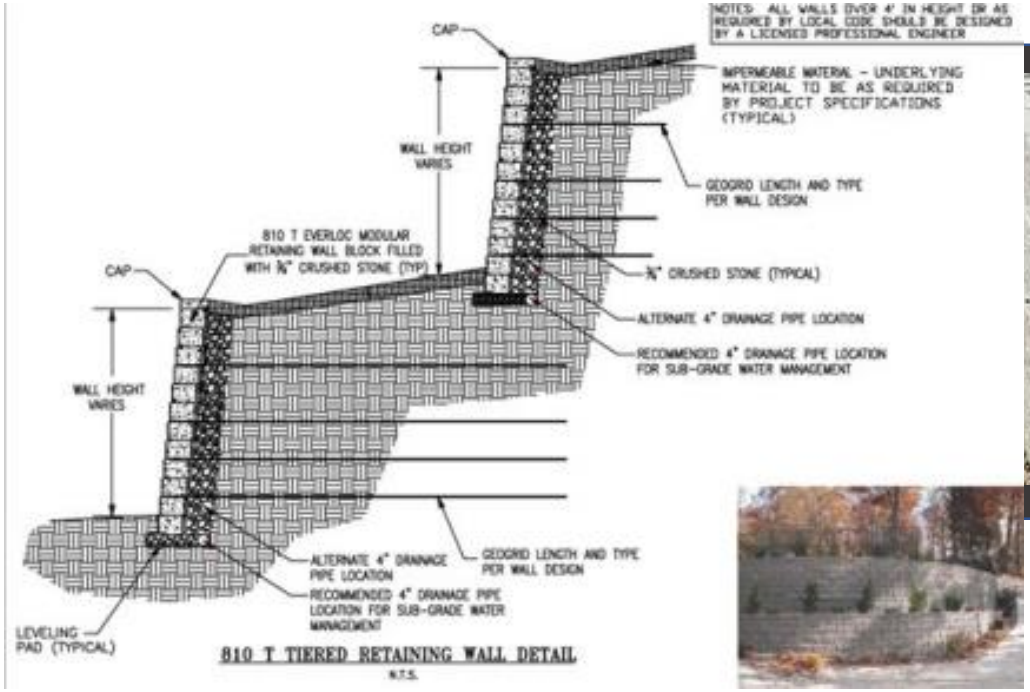
- There will be always the needs for a retaining structure in a development when the ground elevation is varies and the required footprint for development is not enough.



The retaining wall will form part of the country landscape and stands for century

Environmental Green Slope Protection System and Retaining Wall

- Many types of retaining wall has incorporate the requirement of sustainability and resilient. Geogrid reinforced retaining wall is one of the technical proven, economy and sustainable option with at least 30% lower carbon footprint compared with conventional concrete retaining wall (Izzaldin et al., 2018).



Enhancing the appearance of slopes

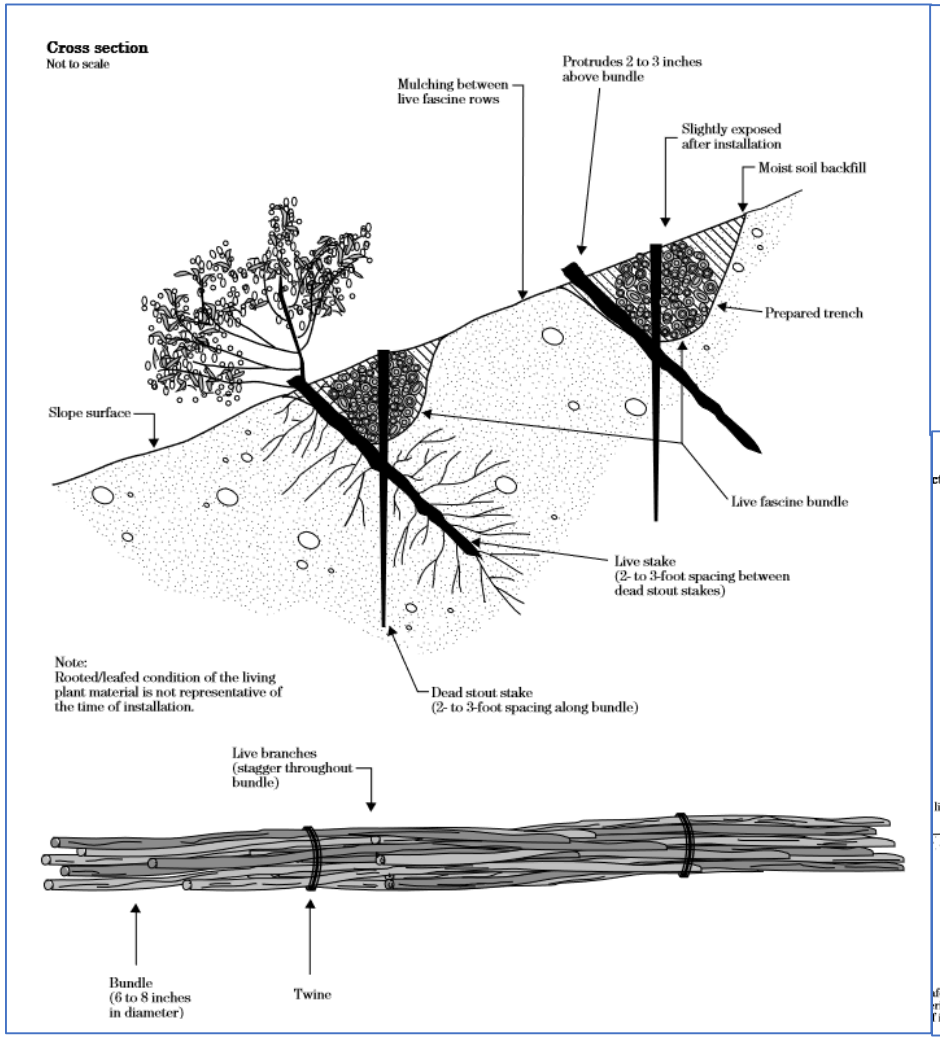
VEGETATED SLOPE OR WALL

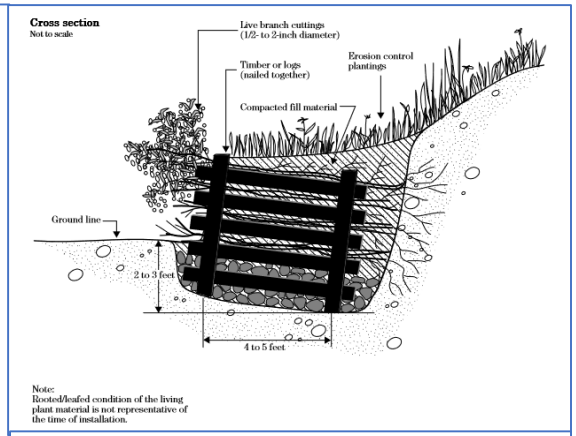
Environmental Green Slope Protection System and Retaining Wall

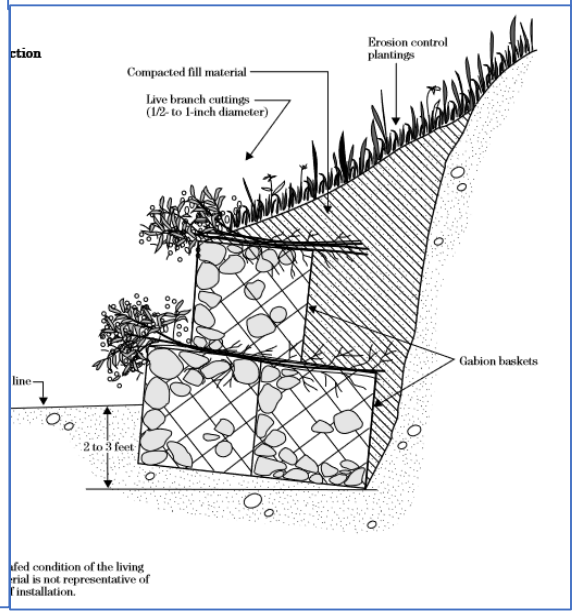
Photos adopted from Newfield Group Deltalok Brochure

Vegetated wall. (before and after)

Environmental Green Slope Protection System and Retaining Wall







Bio-engineering solution for sustainable slope protection

Environmental Green Slope Protection System and Retaining Wall

- The main point for this technology is applying live plants primarily from local sources to create and improve the slope.
- Vegetation on these slope or can be used to manage runoff and its non-point source pollutants with great saving in cost.
- It helps to mitigate the soil erosion problem at slope area.

CONCLUSION

- **Geotechnical engineering has a great potential to influence the sustainability and resilience of a development.**

- **The earlier the sustainability and resilience objectives are considered in a project, the better the outcome** because the availability of sustainable alternatives de-creases as a project proceeds from the planning to the execution stage.

- Hence **early collaboration between geotechnical engineers with all other parties in the project including the architect is very crucial** to enable a holistic approach that considering environmental, social, economic, reliability and resilience aspects from geotechnical perspective is on board timely.

Thank You

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