EARTHWORK

Outline

1.0 Introduction

2.0 Earthwork Activities

3.0 Earthwork Material Assessment
- 3.1 Determination Of Suitable Material
- 3.2 Common Test For Fill Material

4.0 Factors Affecting Compaction

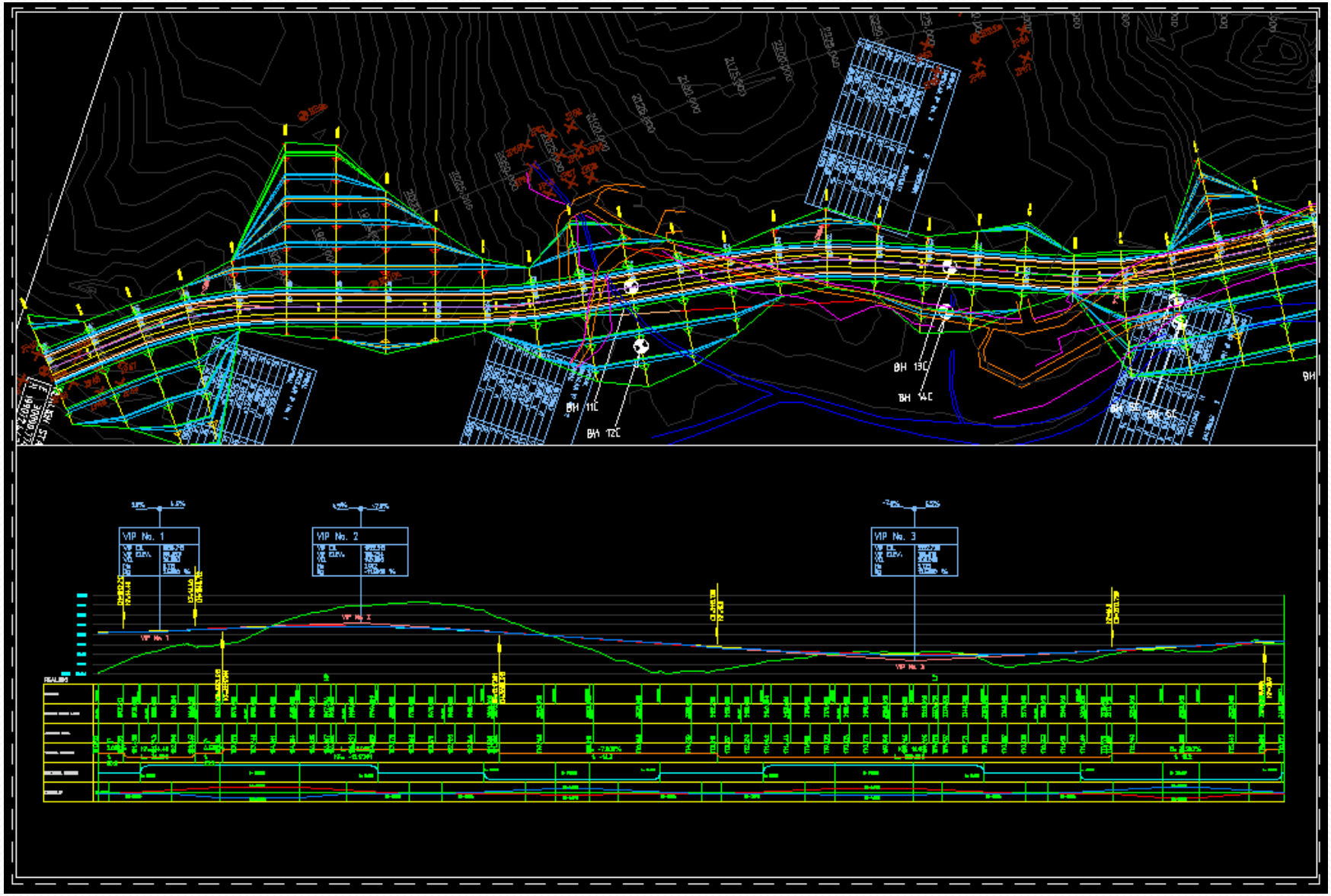
5.0 JKR's Earthwork Specification

6.0 Earthwork Quality Control

Introduction

- Earthwork is one of the important element in Civil Engineering such as road construction, airport, building platform and others.
- Involves preparation of platform as per required in plan profile and cross section.
- In earthwork, many problems arise due to compaction & material quality cause to embankment failure and damage to building.
- This will lead to road closure or evacuation of building and higher cost for remedial works.

Plan and Profile Layout Plan



Cross Section Layout


Compaction Works
5
Excavation Works
2
1 Site Clearing
EARTHWORK ACTIVITIES
6 Sloping Works
Dumping Works
4
Loading Works
3
8/11/2011
Membina Jalan Cherok Paloh-Tanjung Selangor, Kuantan, Pahang

SITE CLEARING

Clearing : Cutting and/or **taking down**, **removal** and **disposal** of everything **above ground level**

Grubbing : Removal and **disposal** of **surface vegetation** to a depth of at least **0.5metre below ground level**

Stripping : **Removal topsoil** to an average depth of at least **100mm below ground level**

Material to be cleared **trees**, **stumps(parts above ground)**, **logs, brush, long grasses, crops, loose material** and etc directs by S.O

SITE CLEARING MACHINERIES

Bulldozer

Grader

EXCAVATION WORKS

Hydraulic Front Shovels

Hydraulic Backhoes (Mass Excavation)

Ripper

Excavator

Normal Excavation

Excavation in any materials which are not rock or artificial hard materials

Hard Material or Rock Excavation

Hard Material / Rock excavation shall mean excavation in any material cannot be loosened by an excavator with a minimum weight of 44 tons and minimum engine rating 321 BHP

Excavator

Excavation using track excavator exceeding weight of **44 tons** and **engine rating of 321 BHP**

Ripper

Ripping using a tractor unit - minimum operating weight of **37 tones** and **engine rating of 305BHP**

Description of Rock

Rock shall mean material found in ledges or masses in its original position which normally have to be loosened either by blasting or by pneumatic tools or, if excavated by hand, by wedges and sledge hammers.

Description of Boulders

Boulders or detached pieces shall only be regarded as rock if they individually exceed 0.5 cubic metre (i.e boulders = rock mass individually less than 0.5 cubic metre)

Operators

The operators shall be competent, in possession of necessary certification/license with **minimum 3 years of experience** in operating the machinery.

Footnote :
BHP (by horsepower)

Open Blasting & Controlled Blasting

The contractor should submit a Master Blasting Plan prepared by qualified and competent staff which includes geotechnical matters and the use of explosives.

All drilling and blasting shall be performed strictly in accordance with the requirements of the S.O, Government and other authorities (Police Department, Fire Engine Department).

Proposed measures needed before commencing any blasting works are as follows:-

1. Copies of current licenses and permits required by Government and other authorities
2. Details and location of work where explosives are proposed to be used
3. Method of transportation to and from the storage magazine and the proposed method of temporary storage at the job site
4. The size, type and location of charges
5. The method of protection
6. The method of firing
7. The time of firing requested
8. The details of warning signals
9. The contractor shall immediately notify the Superintendents of any misfire which occurs and shall advice the location of the misfire and the protection taken work

LOADING WORKS

Wheel Loaders

Off Highway Truck (OHT)

Truck &
Wheel Loaders

DUMPING WORKS

Rear Dump

COMPACTION WORKS

Wheeled Roller

Impact Road Roller

Vibrating Plate

Sheep Foot Roller

SLOPING WORKS

Fill Slope Gradient
1(V):2(H)

Cut Slope Gradient
1(V):1.5H)
1(V):2(H)

Berm width : 2.0m
Berm Height : 6.0m

Excavator

EARTHWORK MATERIAL ASSESSMENT

Determination Of Suitable Material

- Unsuitable material specify according to JKR's Specification:
  - Running silt, peat, log, stumps, perishable or toxic material, slurry or mud or
  - Any material :

    -Consisting of highly organic clay and silt

    -Liquid limit > 80% and/or plasticity index > 55%

    -Loss of weight > 2.5% on ignition

- Materials other than the unsuitable materials defined above is **SUITABLE MATERIAL**

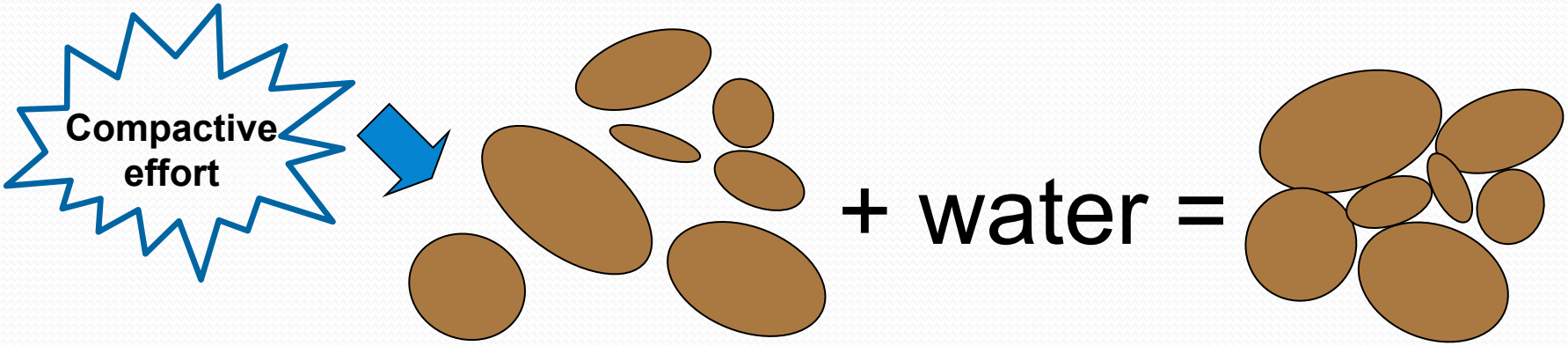
Common Test For Fill Material

- Liquid Limit (LL) and Plasticity Index (PI)
  - To ensure ease of compaction
- Maximum and minimum size of soil particle
  - Gives impact on thickness after and before compaction
- Coefficient of Uniformity
  - To get better particles arrangement and easy for compaction
- Coefficient of Linear Shrinkage
  - To avoid expansion and shrinkage of soil
- California Bearing Ratio
  - Necessity for road subgrade
- Loss of Weight on Ignition (Organic Matter)
  - Control deformation and creep

Compaction

What is compaction?

A simple ground improvement technique, where the soil is densified through external compactive effort.



PURPOSE OF COMPACTION

Increase shear strength
Reduce compressibility
Reduce liquefaction
Control swelling/ shrinkage
Prolong durability

COMPACTION

Objective:
To make sure material used for embankment construction well compacted as per Specification.

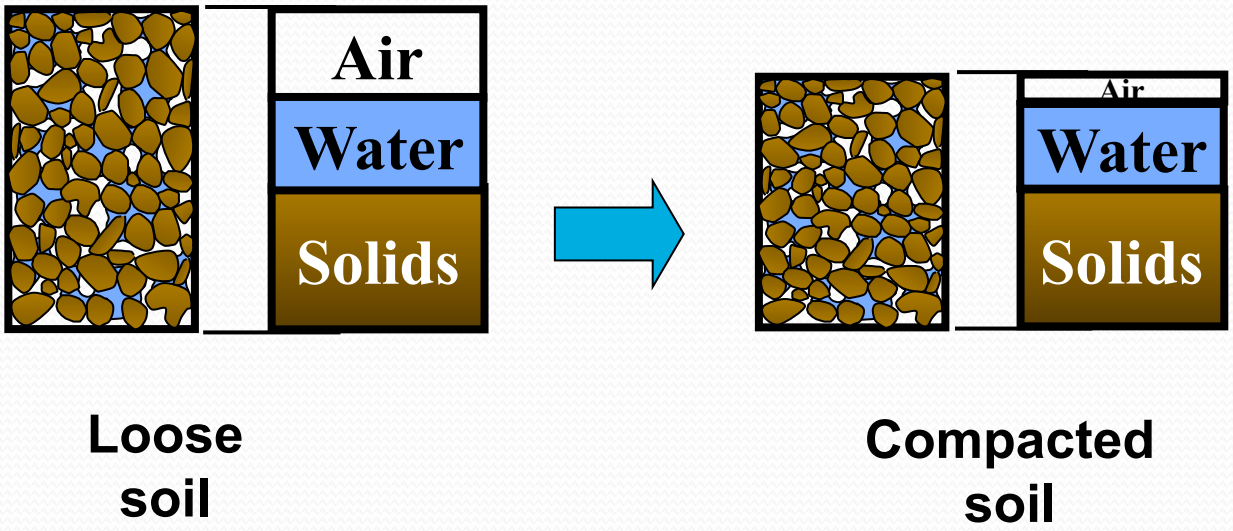
Roadworks

On Site:-

a. Trial Compaction
b. Field Density Test - Sand Replacement Method (BS 1377)

Laboratory:-

a. Modified Proctor Test
b. CBR Test



Factors Affecting Compaction

1. Types of machine used

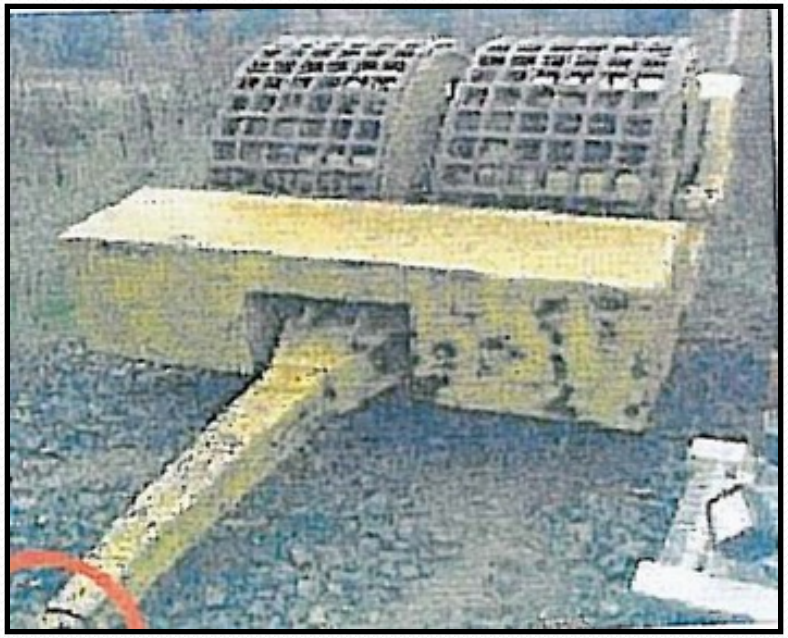
- Modern compaction machine has many functions, such as stress, vibration, static weight etc.

- The choice depends on soil type, construction period and economic factors.

- smooth wheeled roller

- Weight between 2 – 20 tonnes
- Suitable: well graded sand, silt and with low plasticity
- NOT Suitable: uniform sand and soft clay

- grid roller



- Weight between 5-15 tonnes
- Suitable: well graded sand gravel
- NOT Suitable: uniform sand and soft clay

- Sheep foot roller

- Weight between 5 - 8 tonnes
- Suitable: fine grained soil, sand and gravel with fine grained >20%
- NOT Suitable: Coarse grained soil, gravel

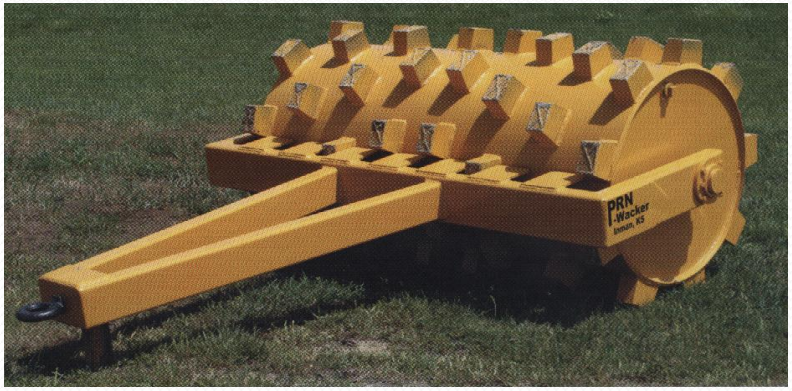
- Pneumatic tyred roller

- Weight between 12 - 40 tonnes
- Suitable: All type of soil
- NOT Suitable: soft clay

SHALLOW SURFACE COMPACTION

Top from left: Grid roller, vibratory plates, vibrating roller and pneumatic rubber roller.

Bottom from left: Smooth-wheeled roller, power rammer and sheepsfoot roller.



COMPACTION MACHINERY

Wheeled Roller

Vibrating Plate

Figure 2. 10: Vibrating plate

2. Thickness of compacted layer

- Determination thickness of layer is crucial to ensure uniform and effective compaction energy throughout compacted layer
- Compaction energy can be determined through Bouissinesg theory.
- The pressure distribution is decreasing with depth.
- After compacted, the density of the soil should reach a maximum value at the specified depth

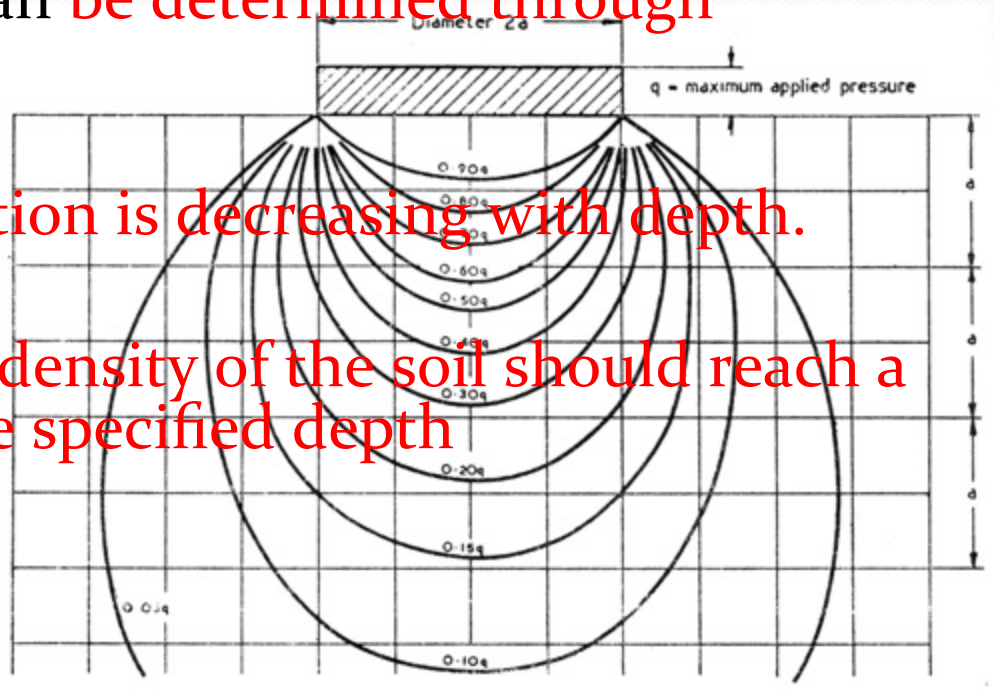
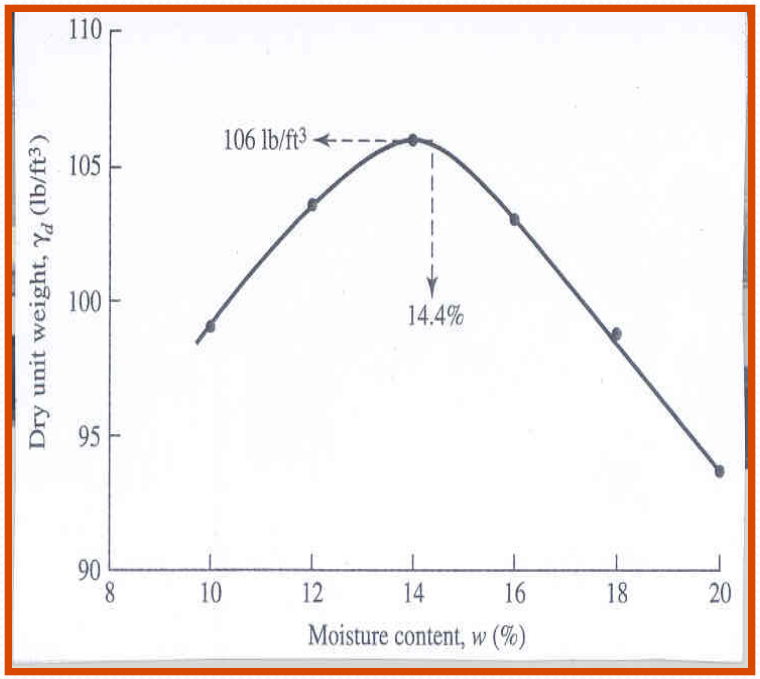


FIG. 22·10 BULB OF PRESSURE UNDER UNIFORM CIRCULAR LOAD

(...con't)

- Too thin also not appropriate due to the lack of confining pressures on the ground.
- Selection of appropriate thickness during compaction is very important
- If the thickness before compacted (loose Thickness) is not controlled, it could happen weak layer / soft layer
- Soft layer formed between two compact layers of an impact such as biscuits 'Oreo'
- This situation will affect / problem to the final product.

3. Moisture Content



- Moisture content of soil is important to control before compaction is made
- Water as lubricant in restructuring of soil particle to become more compact layer
- This process will occur until the excess water out of the soil particles and soil density decreases.
- Moisture content during the maximum density obtained is known as the optimum moisture content (OMC)
- Difficult to achieve good compaction when the soil is too dry or too wet.

4. number of passes

- Compaction depends on the frequency of the burden through a point (number of passes)
- Required number of passes need to be determined through compaction trial (trial compaction).
- Number of passes depends on:
  a) Types of soil
  b) Thickness of layer
  c) Types of machine used
- Practical number of passes between 6 - 10 passes

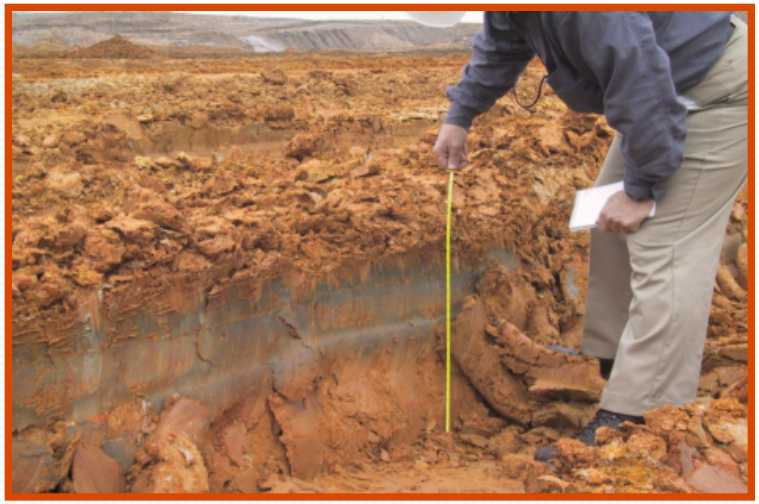
5. Types of soil

- Soil type, size and shape of soil particles and clay content give a huge factor to the maximum dry density and optimum moisture content of the soil
- Generally, granular soils (sand and gravel) easily compacted rather than silt and clay but easily eroded
- Selection of the maximum size of soil to be used is important to ensure that the degree of compaction specified in the specifications can be achieved

The maximum size must be less than the thickness of the densest set

From studies made:

maximum soil size < 2/3 (compacted soil thickness)



JKR's road specification : the maximum thickness of a compacted layer must not exceed 300mm

JKR's EARTHWORK SPECIFICATION

- Road Works
- Building Works

Perkara	JKR Road Specification: SPJ/1998 : Section 2: Earthworks	JKR Building Specification : Section C: Excavation & Earthworks
Bahan Tak sesuai	- Running silt, peat, top soil, highly organic clay or silt - LL > 80%, PI > 55% - Susceptible to spontaneous combustion - Loss of weight > 2.5% on ignition	-Sama-
Trial compaction	- Minimum size 8m x 15m - Fill material for use shall be suitable material - Laid in layers not exceeding 300m compacted thickness - Record type of machine, no of passes & loose depth	-Tiada-
Thickness for every layer	Compacted thickness limit to 300mm	225mm loose depth (external) 155mm loose depth (internal)
Degree of compaction	Based on max dry density B.S.1377 compaction test (4.5 kg rammer) Normal fill : a. Cohesive soil > 90% b. Non cohesive > 95% 300mm subgrade: a. Cohesive soil > 95% b. Non cohesive > 100%	Use 6 tonnes roller – 6 passes
Embankment Slope	Extend each compacted layer to min 600mm beyond the design slope surface	-Tiada-
Field Density Test	Sand replacement method	-Tiada-

Earthwork Quality Control

During Fill Construction

A) Preparation of earth surface

- Need to make sure before embankment is made, the surface is flat, free of stems and roots of trees, plants and unsuitable materials.

- Benching should be made at slope area

B) Equipment and Plant

- Contractors are required to submit the technical specifications of equipment to be used. (Examples of rolling speed, vibration frequency and amplitude)

C) Trial compaction

- Needed to estimate the thickness of the layer to be compacted and the number of passes

  a. Types of machines used

  b. There are significant changes in the material: land resources, and other types.

Equipment

Standard Proof Roller

The proof rolling equipment shall have a loading platform or body suitable for ballast loading that is supported on a minimum of two (2) axles with not more than two (2) pneumatic tyred wheels per axle. All wheels shall be arranged so that they will carry approximately equal loads when operating on uneven surfaces. The spacing of the axle shall have a minimum width of 2.0m.

- The proof roller that using shall have mass per wheel in excess Of 12,000kg with a means of varying the weight up to the above wheel load and the tyre pressure up to 0.85 N/mm². A tyre pressure gauge for measurement shall be provided. The tyre shall be smooth tread and shall impart a minimum ground contact pressure of 520 kPa (75 psi). The operating load and tyre pressure shall be within the range of the manufacturer's chart — directed by the S.o.

Construction Methods

General

When alternative equipment is proposed and the only one axle meets minimum requirements, only the qualifying axle shall be used to proof roll. If the operation of the proof roller shows an area to be unstable, the sub-standard area shall be brought to satisfactory stability and uniformity by additional curing, compaction, or by removal and replacement of unsuitable materials. Them worked area shall then be proof roiled

Operating Speed

The proof roller shall be operated at a speed between 4km/h and 8 km/h or as directed by the SO.

Complete Coverage of Proof Roller

The subgrade shall be proof rolled for a single pass of the proof roller tyres for each of the carriage lane as instructed by the S.O One complete coverage by the proof roller is defined as the complete coverage by the tyre tread of the roller over the entire surface area being tested. Additional trips shall be done if there is a need as directed by the S.O.

Where to Proof Roll

Not with standing the compacted material achieving the required CBR and density, the surface of the subgrade shall be proof rolled. Unless otherwise specified by the S.O, one complete coverage of the proof roller shall be made on a complete sub of embankments and cut sections with the following exceptions and additions.

i. The proof roller shall not be operated within 4.6m of any bridge abutment or retaining wall.
ii. Where proof wiling shows the subgrade to be unstable or to have less than the specified density, such areas shall be corrected by the contractor.

When to Proof Roll

- Proof rolling shall be done immediately after the subgrade compaction operation, when the moisture content of the subgrade soil is near optimum or at the moisture content that achieved compaction.
- Proof rolling shall not be done for areas that are obviously unstable and require undercutting. For areas where subgrade appears to be stable without undercutting, proof rolling shall be done after the top 300mm of the subgrade meets the compaction requirements and after the sub grade has been brought to shape within the specified tolerances.
- Proof rolling may be done either before or after subsoil drains are installed. If done after subsoil drains are installed, proof rolling shall not be done directly over the subsoil drains. Proof rolling shall be performed at least 0.5m away horn the subsoil drains because of the potential damage to the subsoil & drains.

Proof roller Weight and Tyre Pressure

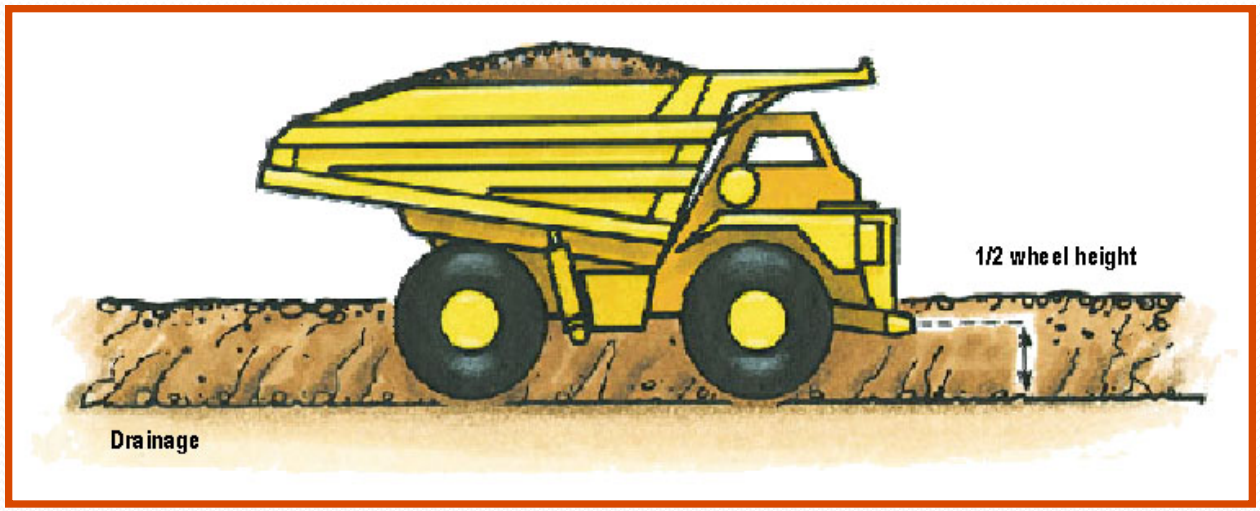
- The weight and Lyre pressure of the proof roller shall be set at a gross weight of 50 tonnes and with a 1020 kPa (150psi) tyre pressure. Close inspections throughout proof roiling shall be done to observe the rolling effects and to mark soft subgrade locations for correction or investigation.

Safety:

- ⊡All workers will be provided with appropriate personal protective equipment (PPE).
- ⊡Workers who fail to comply with this requirement will be removed from site
- ⊡Unauthorized personnel are no permitted within the construction area.
- ⊡Safety officer will closely supervised and checked the safety of the construction area.
- ⊡Safety measures will be intensified the risk are higher during period of works.

D) Filling and compaction works

- Compaction works should be made immediately after earth is placed
- Whenever possible, programmed filling works during dry season so that soil moisture content can be controlled
- Controlled compaction at the optimum moisture content
- Adequate drainage must be made to prevent water stagnation



E) Dealing with too wet soil

- Water should be removed, especially for cohesive soil through aeration or drying under the sun
- Mixing dry soil and wet soil can also be considered

F) Dealing with too dry soil

- Need to add water using sprinkler so that water can be spread uniformly
- Regular watering and cover to prevent drying of the soil

G) Compaction of side slopes embankment

- Slope should be built bigger according to the specifications and trimmed

F) Compaction at structure

- Filling works behind abutment / wing wall should be monitored (eg place settlement marker to monitor the movement of settlement)
- Works should be stopped if large movement is detected
- Compaction works above culvert should used light machine

Before failure

After failure

Test For Quality Control

- Should be done by a representative of SO / PD on site (not delivered to the contractor)

A) Testing in the laboratory

- For earth to be used for fill work should be tested prior suitability

- Reference:
  - made for every borrow pit
  - Testing for every 1500m³ fill material from the same borrow pit

(...con't)

- 1 compaction test for every 2-3 *field density test* (inconsistent soil)
- 1 compaction test for every 5 - 8 *field density test* (consistent soil)

- Among the tests that need to be done:

a. Sieve Test
b. Atterberg Limit
c. Compaction Test
d. CBR (road project: 4 days soak)
e. Loss of Ignition

Atterberg Limit Test

To identify the USM by determination of Liquid Limit (LL) and Plasticity Index (PI).

Criteria for USM:

- Liquid Limit > 80 %
- Plastic Index > 55 %

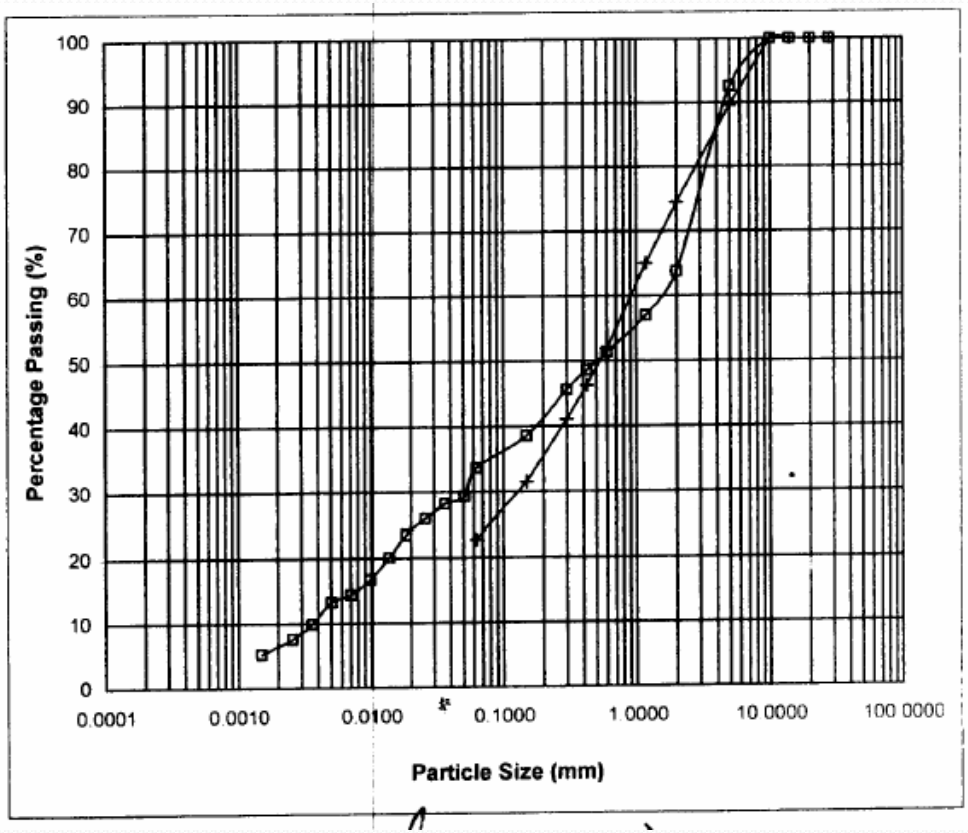
Plastic Index = Liquid Limit – Plastic Limit

Casagrande Equipment to determine Liquid Limit

Method to determine Plastic Limit

Sieve Test

Sieve pan



Particle Size Distribution

Loss of Ignition Test

To determine the organic content.

Criteria for USM :

Loss Of Ignition > 2.5 %

Oven

Scale

Equipment to determine Loss Of Ignition

B) Field density test

- To find out the degree of compaction has met the specifications or not

- Reference:
  - Normal Fill: 1 test/500 m^2 for every layer
  - 300 mm subgrade : 1 test /300 m^2 for every layer

- Among the tests that can be done:

  a. Sand replacement method

  b. Core cutter

  c. Nuclear

Field Density Test

Objective:

To determine the degree of compaction on site accordance to Design/Specification.

Equipment / Method / References: BS 1377: Part 9 : 1990

Sand Replacement Method

Degree of compaction for embankment : below the top 300mm

> 90% for cohesive material

> 95% for non cohesive material

Degree of compaction for 300mm top subgrade :

> 95% for cohesive material

> 100% for non cohesive material

Frequency :

Earth embankment (below the top 300mm of subgrade)

-1 test per 500 m^2 for each layer of compacted material.

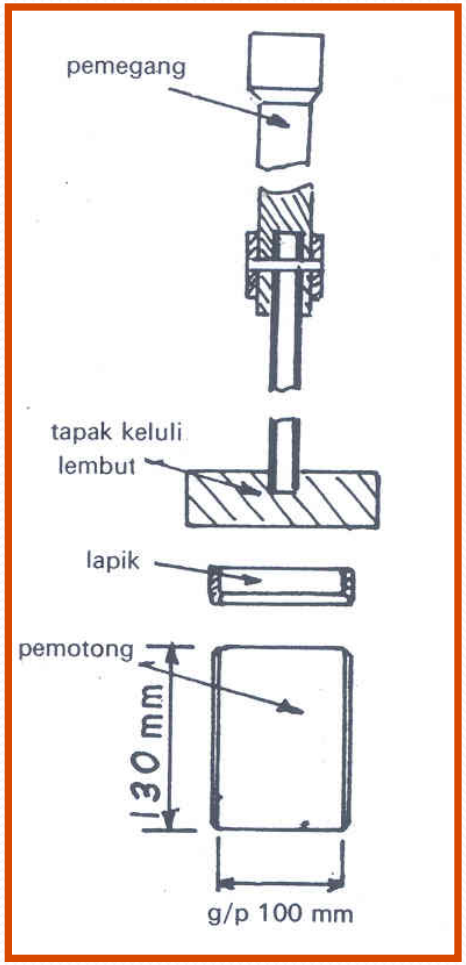
Subgrade

- 1 test per 300 m^2 for each layer of compacted material.

Sand Replacement Method

CORE CUTTER METHOD

CORE CUTTER METHOD



Modified Proctor Test

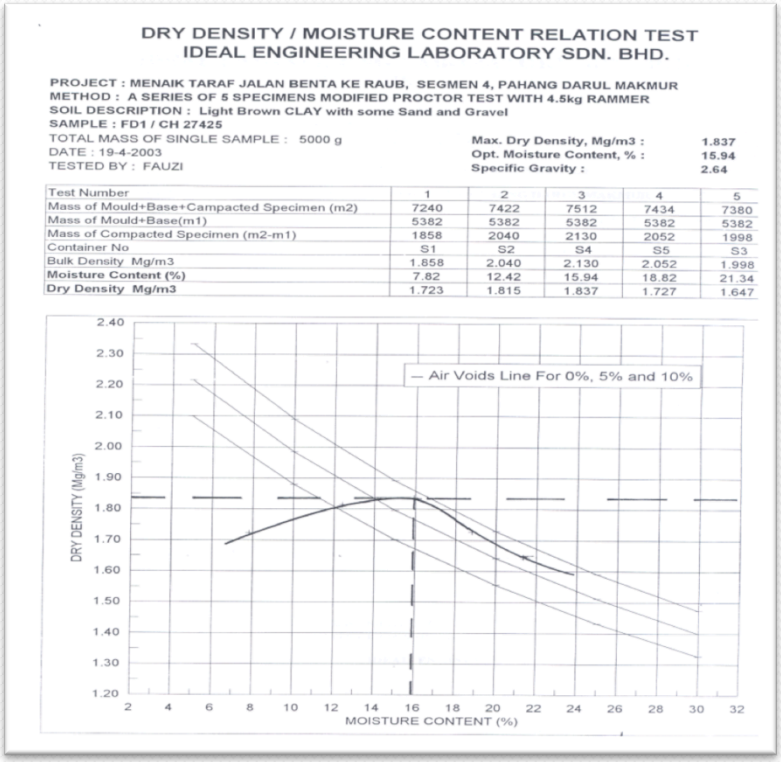
Objective:

To determine the maximum dry density and the optimum moisture content.

- Equipment / Method / References: BS 1377: Part 9 : 1990
- Modified Proctor Test - 4.5 kg rammer method
- Notes:
- Field Density Test (FDT) result (maximum dry density-MDD) is compared to laboratory
- compaction test result (maximum dry density) to determine degree of compaction. The degree of
- compaction is to be in compliance with JKR/SPJ /1988 Section 2.2.4.4 (c)

Compaction Graph

Proctor Test Apparatus



DRY DENSITY / MOISTURE CONTENT RELATION TEST
IDEAL ENGINEERING LABORATORY SDN. BHD.

PROJECT : MENAIK TARAF JALAN BENTA KE RAUB, SEGMEN 4, PAHANG DARUL MAKMUR
METHOD : A SERIES OF 5 SPECIMENS MODIFIED PROCTOR TEST WITH 4.5kg RAMMER
SOIL DESCRIPTION : Light Brown CLAY with some Sand and Gravel
SAMPLE : FD1 / CH 27425
TOTAL MASS OF SINGLE SAMPLE : 5000 g
DATE : 19-4-2003
TESTED BY : FAUZI

Max. Dry Density, Mg/m3 : 1.837
Opt. Moisture Content, % : 15.94
Specific Gravity : 2.64

Test Number	1	2	3	4	5
Mass of Mould+Base+Campacted Specimen (m2)	7240	7422	7512	7434	7380
Mass of Mould+Base(m1)	5382	5382	5382	5382	5382
Mass of Compacted Specimen (m2-m1)	1858	2040	2130	2052	1998
Container No	S1	S2	S4	S5	S3
Bulk Density Mg/m3	1.858	2.040	2.130	2.052	1.998
Moisture Content (%)	7.82	12.42	15.94	18.82	21.34
Dry Density Mg/m3	1.723	1.815	1.837	1.727	1.647

NUCLEAR METHOD

Supervision and Monitoring

✓ A monitoring program should include information on what needs to be checked and recorded, frequency and acceptance criteria.

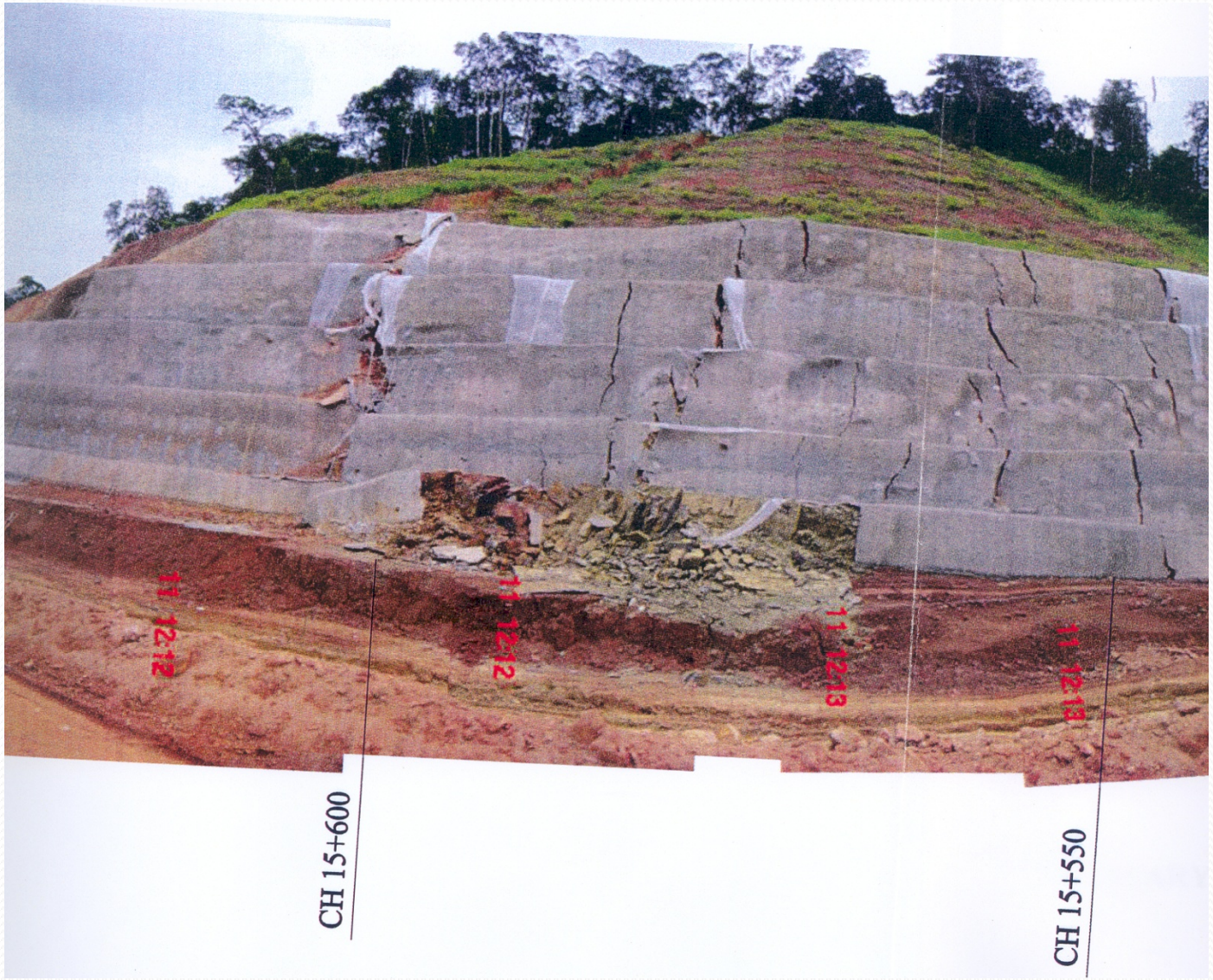
✓ Should provide a checklist for surveillance.

PROBLEMS DURING EARTHWORK

- EROSION
- AIR POLLUTION
- NOISE POLLUTION
- WATER POLLUTION
- SLOPE FAILURE
  - CUT AREA
  - FILL AREA
- RIVER DIVERSION

SLOPE FAILURE PROBLEM

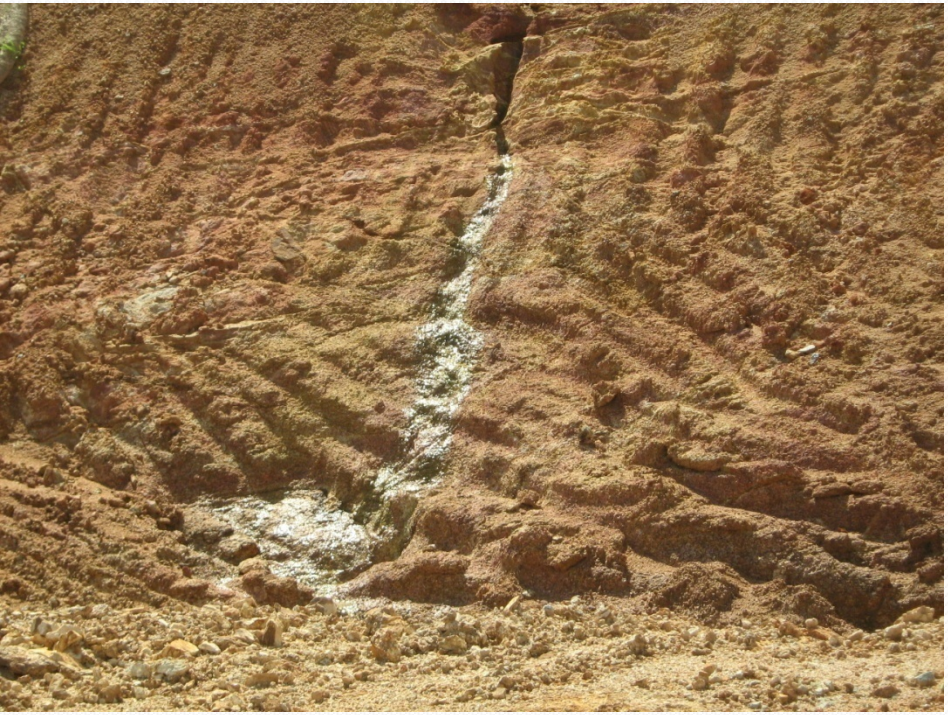
SLOPE FAILURE PROBLEM



EARTHWORK PROBLEM - RIVER DIVERSION

EARTHWORK PROBLEM – WATER & USM

EARTHWORK PROBLEM – CUT SLOPE : GROUND WATER



EARTHWORK PROBLEM – RELOCATION OF UTILITIES

END OF SLIDES PRESENTATION
thank you