

# THE ROLE OF TIME DEPENDENT ANALYSIS TO IMPROVE ENVIRONMENTAL MANAGEMENT SYSTEM IN MINE CLOSURE PLAN IN OPEN PIT MINE

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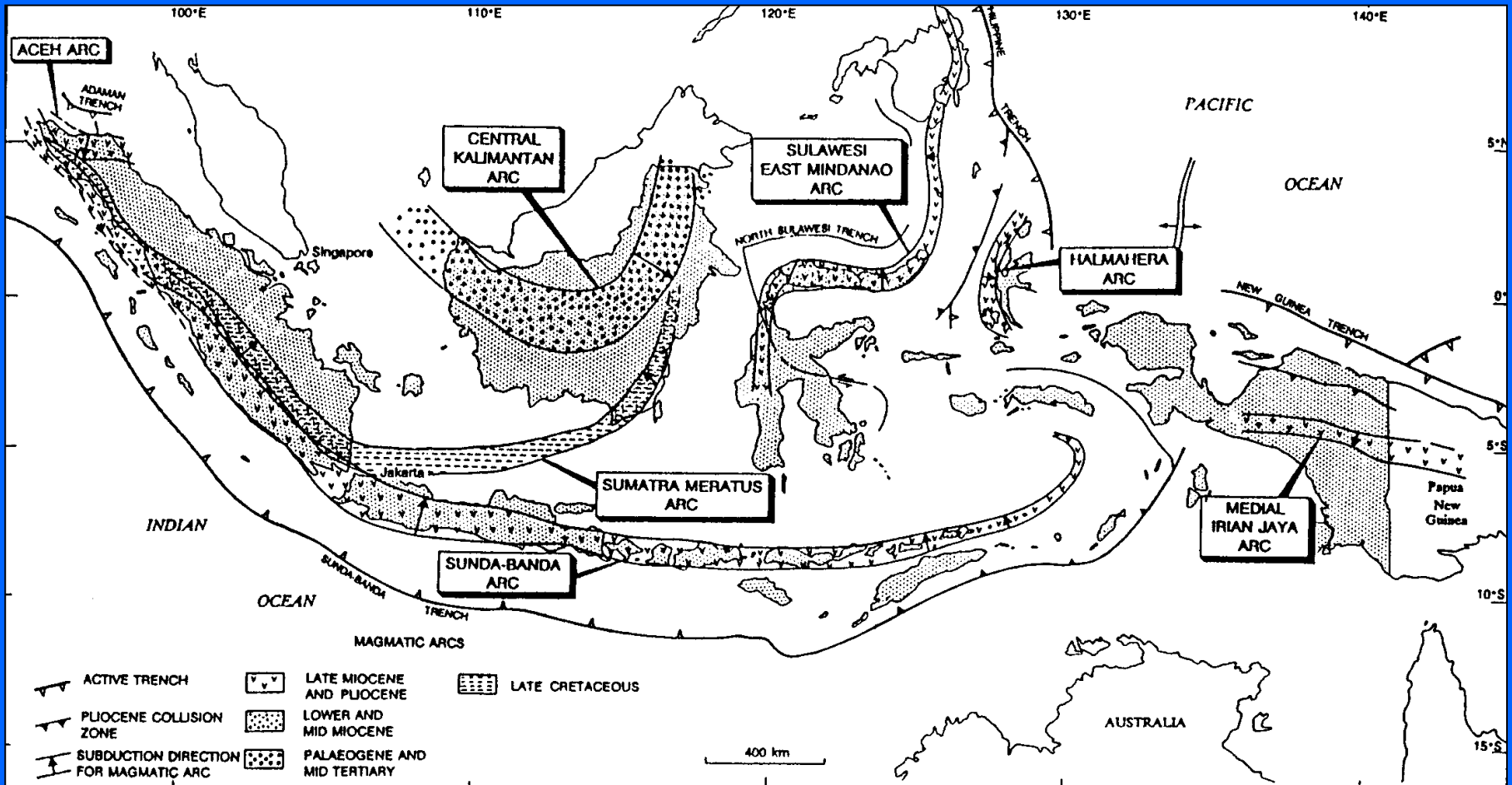
# INTRODUCTION

- Mining sequence: geological reconnaissance, exploration, exploitation, processing, marketing and mine closure.
- Mine closure has been the center attention for stakeholders.
- Three mines closed down & there will be 9 more mine closures.
- Exploitation results a large amount of waste geo-materials & tailing in form of physical features: embankment, pits, excavated slopes, overburden dumps and tailings dam.
- Stability of these features is important upon mine closure.
- Importance of long-term shear strength, which is part of creep phenomenon or time dependent analysis.
- Provide input for the mine closure technical guideline.

# THE UNIQUENESS OF GENERAL GEOLOGY & CLIMATE OF INDONESIA

- About 80 - 90% is covered by quarter sediment: alluvial, clastic, & pyroclastic sediments from volcano activities.
- Experiences strong and frequent tectonic activities.
- Located within the Equator & between Asia & Australia continents & surrounded by Pacific and Indian oceans, hence it is exposed to high annual rainfall rate of 3000 - 4000 mm.
- High ambient temperature and intensity of ultraviolet ray over a year period are relatively high and cause intensive weathering.

# BELTS OF MINERAL POTENTIAL IN INDONESIA



# TAILINGS DAM & SLOPE STABILITY

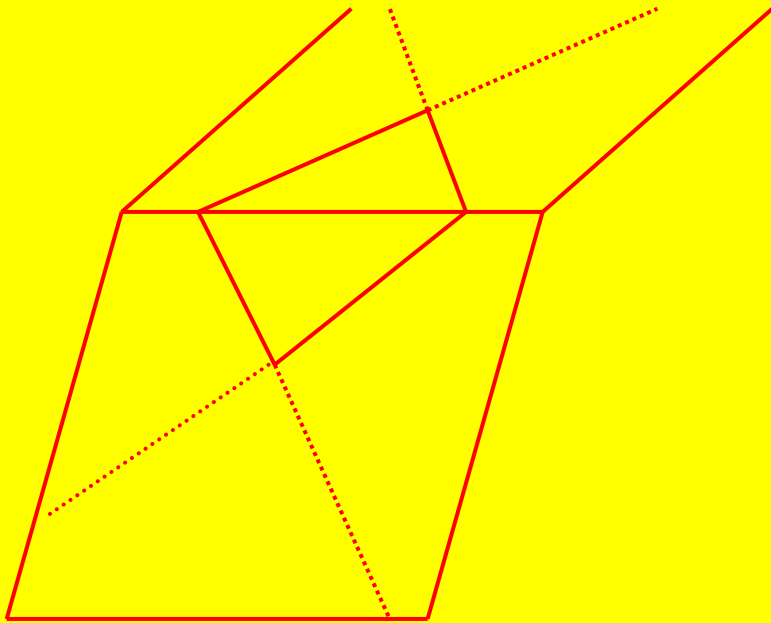
- MC plan must address long-term physical, chemical stability & land-use issues.
- Failure of excavated slopes, & overburden dumps will lead to the process of depositing sediment along downstream.
- Failure of tailings dam will bring about more severe problems.
- MC plan must consider stability of slope & tailings dam.
- Weathering plays significant role in dam failures.
- During 1965-1981, of 35 incidents about 80% of tailings dam failures attributed to earthquake and heavy rainfall.
- Mass movement is typical to tailings dam & mine slope stability & this is due to geometry, rainfall, weathering, cohesion reduction.
- Time dependent behaviour of geo-materials has been analysed based upon creep test at laboratory.

# CASE STUDY

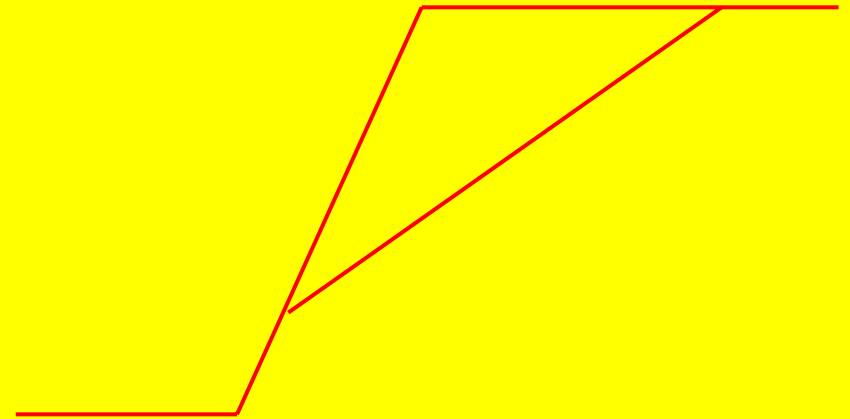
- Air Laya & North Muara Tiga Besar in Tanjung Enim area, south Sumatra & operated by the PT. Bukit Asam.
- Wedge type slope failure has been the most common one occurring at the Air Laya mine.
- A stereonet analysis indicates four joint sets intersected each other at the Air Laya mine.
- The failure is due to shear characteristics deterioration.
- Planar failure was encountered at the southern part of the North Muara Tiga Besar mine.
- Failure analysis revealed that weathering could significantly reduce the strength of the interface materials at the joints.

# SLOPE FAILURES CONTROLLED BY GEOLOGICAL STRUCTURE

Wedge failure



Planar failure



# CIRCULAR SLOPE FAILURE AT NORTHERN PART OF NORTH MUARA TIGA BESAR MINE

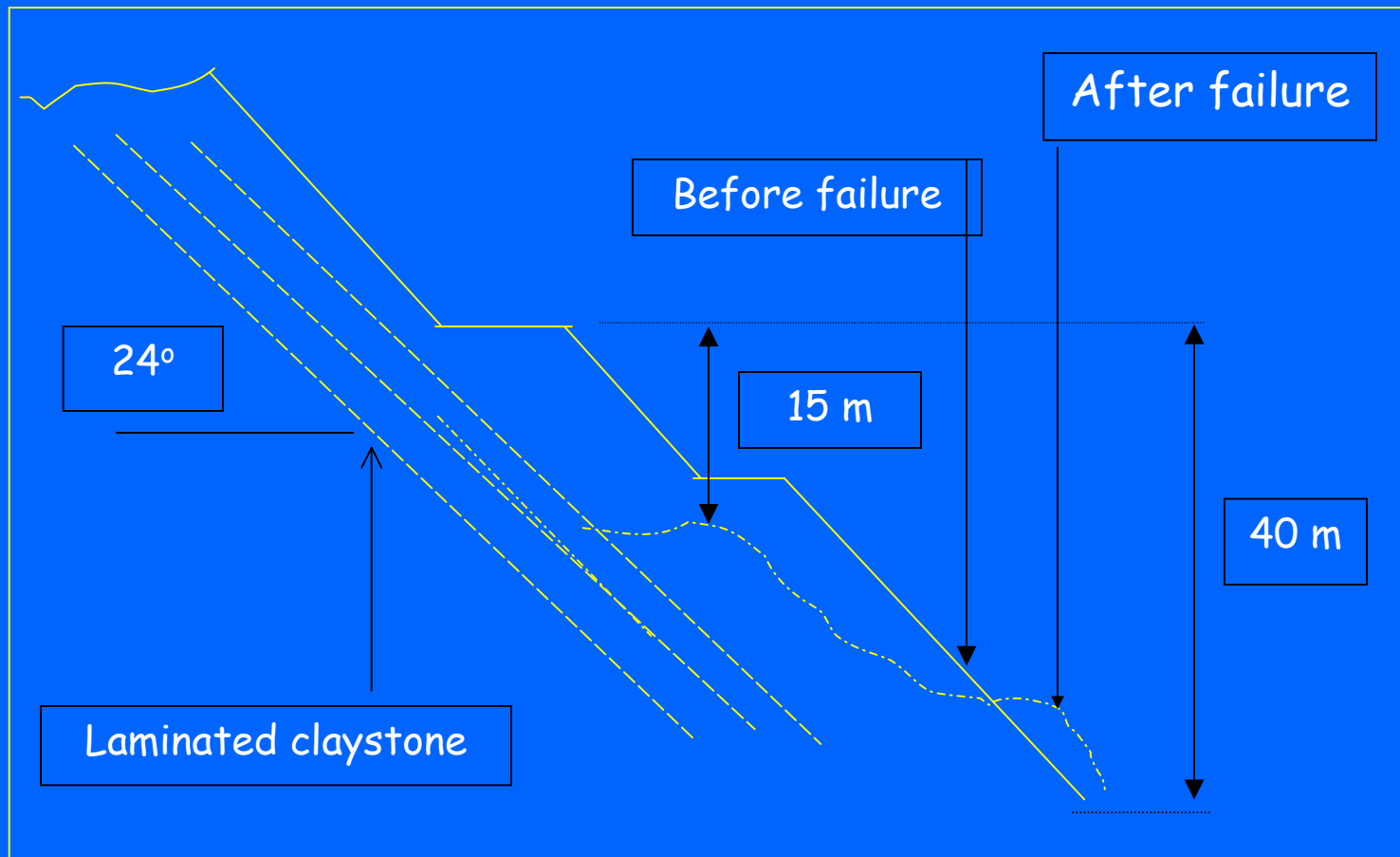




# PLANAR FAILURE AT SOUTHERN PART OF NORTH MUARA TIGA BESAR



# CROSS SECTION OF BEFORE AND AFTER PLANAR FAILURE



# FAILURE ANALYSIS

- Overburden at Muara Tiga Besar is dominated by claystone.
- Average annual rainfall is of 3000 mm.
- Overall height of slopes is up to 80 m.
- Average overall slope of 20° is considered optimum.
- Individual slopes remain stable at max. height of 40 m and 35°.
- Designed SF of overall and individual slopes 1.35 to 3.6.
- Having remained standing for 18 months, failure took place at some of the slopes.
- Shear creep tests on claystone samples obtained from the failure area were carried out at the Laboratory of Geomechanics of the Department of Mining Engineering, Institut Teknologi Bandung.

# FAILURE ANALYSIS

- Claystone time dependent behavior follows Burger rheology model. Long-term shear strength of claystone levels off at about 40% of its peak strength after about 240 days (8 months).
- SF of the slope decreases from 3.6 to 1.4, stable.
- $C$  and  $\phi$  decrease with time;  $C = 513.8 t^{-0.24}$  -  $\phi = 73 t^{-0.20}$  ( $t = \text{day}$ ).
- The slope failed in 18 months after construction.
- SF based on  $C$  &  $\phi$  for 18 months is 1.17, unstable.
- Shear creep data offers an alternative approach in assessing stability of a slope.
- Weather can be represented in the time dependent analysis.
- Time dependent analysis has been used for U/G stability analysis.

# DISCUSSION AND RECOMMENDATIONS

- The Directorate General of Geology and Mineral Resources of the Government of Republic Indonesia has realized that MC present a complex mixture of environmental, social, economic & development issues.
- The MC plan will have to be carried out to the satisfaction of the stakeholders.
- Some mine closure and rehabilitation plans may provide for recreational or other facilities intended to offset any adverse environmental effects and to benefit the community in the longer term.
- Post-closure long-term management costs of open-pit mine will largely depend on the geomechanical and chemical properties of the geo-materials, the design and construction of the slopes or dams.

# DISCUSSION AND RECOMMENDATIONS

- Needs of understanding of the geo-materials, local climate & seismic events.
- Dam failures were mostly caused by natural catastrophes and lack of attention to the design parameters that were not considered.
- Conduct detailed site investigation prior to the design and construction of the physical features.
- Time dependent analysis may be included in mine closure plans.
- Perform routine monitoring and periodic safety audits for observed conditions during mine life and upon the mine closure.
- The mine closure should complete the physical environmental rehabilitation in a satisfactory manner and the community could obviously further use and develop the land to maintain a sustainable existence.