

PENGARUH MINERAL LEMPUNG TERHADAP  
POTENSI HAKISAN TANAH BERGERUN  
BERDASARKAN MEKANISME PENYERAKAN  
DAN PENGASINGAN

AZLAN SHAH BIN NERWAN SHAH @ NINTIN

UNIVERSITI KEBANGSAAN MALAYSIA

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BERCERUN BERDASARKAN MEKANISME PENYERAKAN DAN  
PENGASINGAN

AZLAN SHAH BIN NERWAN SHAH @ NINTIN

TESIS YANG DIKEMUKAKAN UNTUK MEMPEROLEH  
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FAKULTI SAINS DAN TEKNOLOGI  
UNIVERSITI KEBANGSAAN MALAYSIA  
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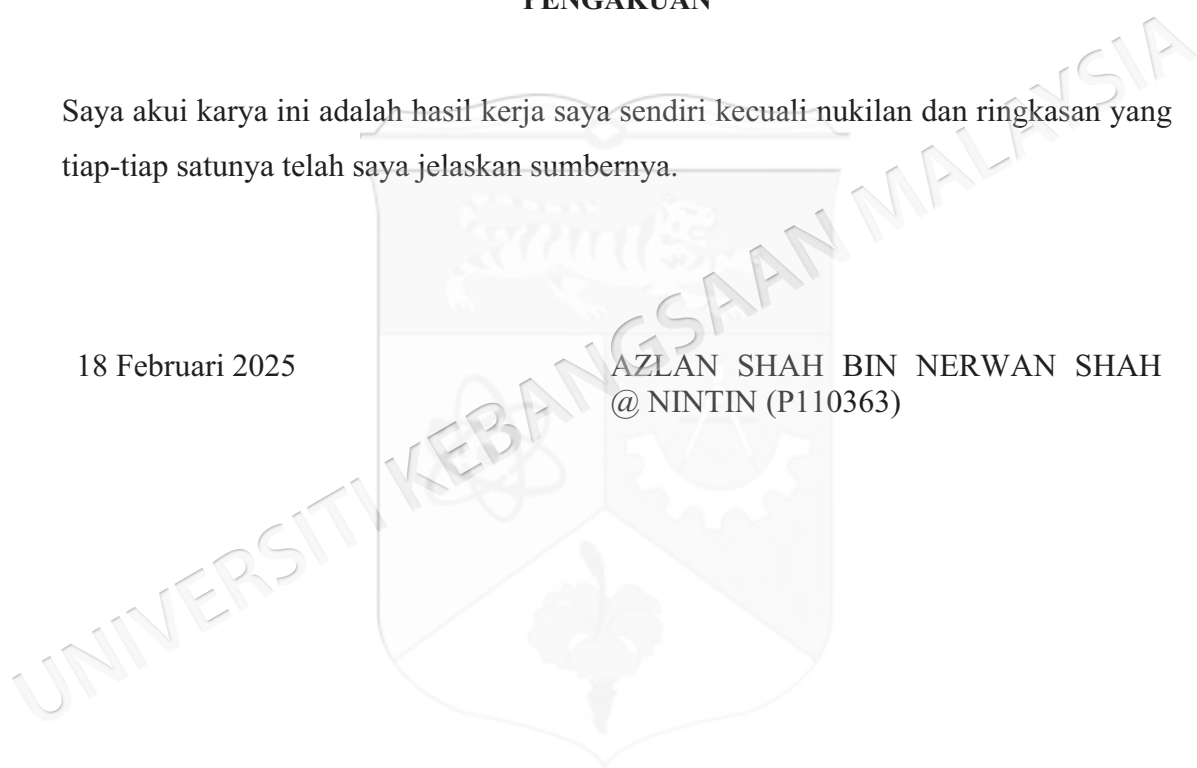
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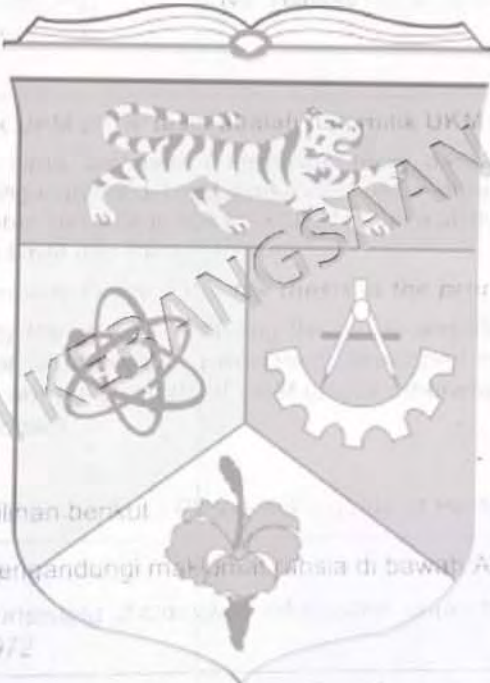
PERAKUAN TESIS SARJANA / DOKTOR FALSAFAH  
(DECLARATION OF MASTER / DOCTOR OF PHILOSOPHY THESIS)

A. MAKLUMAT PELAJAR/STUDENT DETAILS

Nama Name	AZIAN SHAH BIN NURWAN SHAH BIN NURIN
No. Pendaftaran Registration No.	PT10163
Fakulti/Institut Faculty/Institution	SAINS DAN TEKNOLOGI
Program/Pengajian Program of study	Sarjana / Doctoral Philosophy   Master / Doctoral Philosophy
Jajuk Tesis Thesis Title	PENGARUH MINERAL LEMPUNG TERHADAP POTENSI HAKISAN TANAH BERGERUN BERHADAPAN MIKROBIOME PENYERAPAN DAN PENGASINGAN
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## PENGHARGAAN

Alhamdulillah.

Syukur ke hadrat Ilahi kerana dengan izin-Nya, saya dapat menyelesaikan kajian ini dengan jayanya. Sejujurnya, saya tidak menjangka akan berada pada tahap ini. Penghargaan ini saya dedikasikan kepada penyelia utama, YBrs. Dr. Nor Shahidah Mohd Nazer dan YBrs. Prof. Madya Ts. Dr. Mohd Hariri Arifin selaku penyelia bersama di atas bimbingan, nasihat dan bantuan yang diberikan sepanjang pengajian saya di Universiti Kebangsaan Malaysia (UKM). Segala teguran membina dapat dijadikan sebagai panduan untuk merangka analisis secara kritikal dalam kajian ini. Penghargaan ini juga dipanjangkan kepada para pemeriksa luar dan dalam di atas ulasan dan cadangan bagi menambahbaik penulisan dan interpretasi data tesis ini. Dedikasi ini juga ditujukan kepada Jabatan Sains Bumi dan Alam Sekitar (JSBAS), Pusat Penyelidikan dan Instrumentasi (CRIM), UKM serta Agensi Nuklear Malaysia di atas kemudahan fasiliti yang disediakan bagi tujuan penyelidikan kajian ini. Ucapan penghargaan ini turut ditujukan kepada kakitangan JSBAS yang banyak membantu dalam konteks aktiviti penyelidikan di makmal.

Seterusnya, ucapan penghargaan ditujukan kepada kepada kedua ibu bapa saya, Nintin bin Balak dan Sabtariah binti Ismail (ibu tiri) serta adik-beradik saya di atas sokongan moral dan emosi yang diberikan. Dedikasi khas ini juga ditujukan allayarhamah ibu saya, Masria binti Mamai di atas pengorbanan melahirkan saya di dunia ini. Tanpa beliau, saya tidak akan berada di sini untuk merealisasikan impian ini. Tidak lupa juga kepada rakan-rakan khususnya Mohamad Qamaruddin Rokei, Mohammad Faizul Asmat, Amer Hazreq Haron, Ahmad Hambali Ismail, Muhammad Isha Haris dan Norhaslinda Hasan yang memberikan kata semangat dan sokongan sepanjang tempoh pengajian. Dedikasi ini turut ditujukan kepada Leftenan Komander Mohd Edie Mohd Khalil di atas motivasi dan contoh teladan yang diberikan untuk saya menyambung pengajian di peringkat tertinggi ini. Akhir sekali, saya ingin mengucapkan terima kasih kepada semua pihak lain yang terlibat secara langsung dan tidak langsung dalam menjayakan kajian ini.

Akhir kata, semoga hasil penyelidikan ini dapat menjadi satu panduan berguna dan dapat dimanfaatkan kepada negara dan komuniti secara holistik pada masa hadapan bagi menghadapi cabaran globalisasi dan perubahan iklim setempat dalam konteks kejuruteraan geologi tanah di Malaysia.

Terima kasih Allah S.W.T.

## ABSTRAK

Mineral lempung merupakan bahan mudah terhakis yang wujud sebagai sebahagian komponen tanah baki dengan litologi batuan yang berbeza. Serakan dan pengasingan merupakan mekanisme hakisan utama apabila mineral lempung berinteraksi dengan air. Kemampuan tanah untuk terhakis secara permukaan dan dalaman berpotensi untuk menyumbang kepada kejadian tanah runtuh. Objektif kajian ini dijalankan untuk mencirikan sifat fiziko-kimia tanah baki, menentukan kebolehpayaan serakan tanah berdasarkan jenis mineral lempung, mengukur morfometrik rekahan dan menentukan kadar pengasingan bagi melihat kebolehpayaan tanah untuk terhakis di bawah pengaruh penyerakan dan daya aliran air. Pengukuran kadar pengasingan tanah dijalankan melalui simulasi flum menggunakan sampel tanah kering manakala ujian penyerakan lubang pin menggunakan sampel tanah lembab. Kawasan persampelan tanah baki melibatkan beberapa kawasan cerun di negeri Sabah, Selangor, Kedah dan Negeri Sembilan dengan berpandukan kepada tiga jenis batuan induk yang berbeza (igneus, metamorf, sedimen). Berdasarkan analisis sifat indeks, tanah baki sedimen merekodkan kandungan lempung ( $L_g$ ) yang lebih tinggi dengan julat 3.08–43.70% berbanding tanah baki igneus (1.49–5.08%) dan metamorf (0.26–9.30%). Tanah baki sedimen mempunyai kewujudan mineral dominan seperti kuarza di samping variasi mineral lempung seperti kaolinit, ilit, montmorilonit dan vermikulit yang mempengaruhi kapasiti pengembangan-pegecutan tanah. Analisis tahap serakan menunjukkan mineral lempung montmorilonit lebih cenderung untuk terserak diikuti ilit, kaolinit dan vermikulit. Analisis morfometrik rekahan tanah menunjukkan tanah terserak merekodkan nilai faktor intensiti rekahan (CIF) dan faktor ketumpatan rekahan (CDF) yang lebih tinggi berbanding tanah tidak terserak dengan masing-masing berjulat 16.70–28.20% dan 27.99–38.90%. Nilai pengasingan tanah terserak yang ditentukan daripada simulasi flum adalah lebih rendah dengan julat 0.000174–0.000328 kg/m<sup>2</sup>/s berbanding nilai pengasingan daripada ujian penyerakan lubang pin dengan julat 0.01252–0.02055 kg/m<sup>2</sup>/s. Analisis komponen prinsipal (PCA) menjelaskan hakisan dalaman adalah dipengaruhi oleh faktor serakan tanah manakala hakisan permukaan lebih dipengaruhi oleh daya dan kuasa aliran air. Pemerhatian menunjukkan tindakan aliran air di permukaan tanah menyebabkan hakisan mengufuk lebih dominan berbanding hakisan menegak akibat pembebasan tekanan ke atas permukaan yang luas. Sebaliknya, penumpuan aliran air di dalam ruang terkekang (*confined*) di dalam tanah menyebabkan penumpukan tenaga di kawasan yang lebih kecil sekaligus menyebabkan hakisan menegak lebih dominan berbanding hakisan mengufuk. Keadaan ini menyumbang kepada pembukaan rongga tanah secara paip dan mengurangkan ketumpatan tanah lalu membentuk zon lemah di dalam tanah. Secara keseluruhannya, kadar pengasingan minimum tanah untuk terhakis secara dalaman adalah 66 kali ganda lebih tinggi berbanding hakisan permukaan. Keadaan ini membuktikan kapasiti ketahanan tanah terhadap hakisan adalah sangat rendah di sub-permukaan berbanding permukaan walaupun tindakan air lebih dominan di permukaan. Dominasi hakisan dalaman berbanding permukaan juga menyebabkan kaviti tanah meningkat secara agresif di bawah pengaruh serakan dan berpotensi membentuk zon lemah yang mampu mengganggu struktur tanah. Penemuan ini juga menunjukkan faktor hakisan dalaman tanah perlu diberi perhatian dalam menilai kestabilan cerun tanah terserak bagi mengawal risiko pembentukan satah gelinciran yang berpotensi menyebabkan kejadian tanah runtuh.

## THE INFLUENCE OF CLAY MINERALS ON SOIL EROSION POTENTIAL ON SLOPES BASED ON THE MECHANISMS OF DISPERSION AND DETACHMENT

### ABSTRACT

Clay minerals are easily erodible materials that exist as part of the residual soil components with varying rock lithology. Dispersion and detachment are the main erosion mechanisms when clay minerals interact with water. The ability of soil to erode, both on the surface and internally, has the potential to contribute to landslide occurrences. The objective of this study is to characterize the physico-chemical properties of residual soil, determine the detachment capacity of the soil based on clay mineral types, measure the morphometric characteristics of cracks and assess the detachment rates to evaluate the soil's susceptibility to erosion under the influence of dispersion and water flow forces. The measurement of soil detachment rates was conducted through flume simulations using dry soil samples, while pinhole dispersion tests were performed using wet soil samples. The sampling areas involved several slopes in the states of Sabah, Selangor, Kedah and Negeri Sembilan, guided by three different types of parent rocks (igneous, metamorphic, sedimentary). Based on index property analysis, sedimentary residual soil recorded a higher clay content ( $L_g$ ) ranging 3.08–43.70% compared to igneous (1.49–5.08%) and metamorphic soils (0.26–9.30%). Sedimentary residual soil contains dominant minerals like quartz, along with variations of clay minerals such as kaolinite, illite, montmorillonite, and vermiculite which influence the swelling-shrinkage capacity of soils. Morphometric analysis of soil cracks shows that dispersive soil has higher crack intensity factor (CIF) and crack density factor (CDF) values compared to non-dispersive soil, ranging 16.70–28.20% and 27.99–38.90%, respectively. The detachment values of dispersive soils determined from flume simulation are lower with a range of 0.000174–0.000328 kg/m<sup>2</sup>/s, compared to detachment values from the pinhole dispersion test ranging 0.01252–0.02055 kg/m<sup>2</sup>/s. Principal component analysis (PCA) indicates that internal erosion is influenced by soil detachment factors, while surface erosion is more influenced by the force and power of water flow. Observations indicate that the action of flowing water horizontally on the soil surface causes predominantly horizontal erosion compared to vertical erosion due to pressure release on a large surface area. Conversely, the concentration of water flow in confining spaces within the soil leads to the accumulation of energy in smaller areas, thereby causing vertical erosion to be more dominant than horizontal erosion. This contributes to the formation of soil cavities in a pipe-like manner and reduces soil density drastically, thus forming weak zones within the soil. Overall, the minimum soil detachment rate for occurrence of internal erosion is over 66 times higher than surface erosion. This demonstrates that the resistance capacity for soil to erode is significantly lower below surface compared to the surface, even though water action is more dominant on the surface. The dominance of internal erosion over surface erosion also causes soil cavities to increase aggressively under the influence of dispersion, potentially forming weak zones that causes soil structure disturbance. These findings also indicate that internal soil erosion factors need to be considered in assessing slope stability of dispersive soil to control the risk of sliding slip formation that may potentially caused landslide incident.

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## SENARAI SINGKATAN

ACA	Purata Bukaak Rekahan
AEV	Nilai Masuk Udara
CDF	Faktor Ketumpatan Rekahan
$C_e$	Pekali Kebolehakisan
CEC	Kapasiti Pertukaran Kation
CIF	Faktor Intensiti Rekahan
CREAMS	Bahan Kimia, Larian Dan Hakisan Daripada Sistem Pengurusan Pertanian
D	Tanah Terserak
DDL	Lapisan Terserap Berganda
<i>Dr</i>	Kadar Pengasingan
ESP	Peratus Natrium Boleh Tukar
EUROSEM	Model Hakisan Tanah Eropah
FESEM	Mikroskop Elektron Pengimbas Pelepasan Medan
FS	Tanah Bersaiz Halus
FST	Ujian Pengembangan Bebas
$G_s$	Graviti Tentu
HET	Ujian Hakisan Lubang
<i>I</i>	Indeks hakisan dalaman
ICP-MS	Spektrometri Jisim Plasma Gandingan Aruhan
IS	Tanah <i>In Situ</i>
$I_w$	Indeks Luluhawa
JET	Ujian Hakisan Jet
JMG	Jabatan Mineral dan Geosains
LL	Had Cecair

L <sub>s</sub>	Pengecutan Linear
ND	Tanah Tidak Terserak
NRMSE	Punca Min Ralat Kuasa Dua Normalisasi
NSE	Kecekapan <i>Nash-Sutcliffe</i>
OC	Kandungan Organik
PCA	Analisis Komponen Prinsipal
PI	Indeks Keplastikan
PL	Had Plastik
PSD	Taburan Saiz Butiran
RECT	Ujian Silinder Hakisan Berputar
SAR	Nisbah Penjerapan Natrium
SD	Tanah Sederhana Terserak
SET	Ujian Hakisan Slot
SRA	Luas Pengecutan Sampel Asal
SSA	Luas Permukaan Spesifik
TCA	Jumlah Luas Rekahan
TCL	Jumlah Panjang Rekahan
TCS	Jumlah Segmentasi Rekahan
WEPP	Projek Ramalan Hakisan Air
XRD	Analisis Pembelauan Sinar-X

## SENARAI SIMBOL

$\text{Ca}^{2+}$	Ion Kalsium
$F_r$	Nombor Froude
$\text{K}^+$	Ion Kalium
$\text{Mg}^{2+}$	Ion Magnesium
$\text{Na}^+$	Ion Natrium
$Q$	Kadar Aliran
$R$	Jejari Hidraulik
$r$	Pekali Korelasi
$R^2$	Pekali Penentuan
$Re$	Nombor Reynold
$v$	Halaju Aliran
$v_c$	Halaju Aliran Kritikal
$w$	Kandungan Kelembapan Tanah
$\tau$	Tegasan Ricih Aliran
$\tau_c$	Tegasan Ricih Kritikal
$\Omega$	Kuasa Aliran
$\Omega_c$	Kuasa Aliran Kritikal

## BAB I

### PENGENALAN

#### 1.1 PENDAHULUAN

Kedudukan Malaysia yang terletak berhampiran garisan khatulistiwa dan beriklim tropika menyumbang kepada tindak balas fizikal dan kimia yang pesat pada batuan berikutan faktor kerpasan yang tinggi serta keamatan suhu panas sepanjang tahun. Keadaan ini menghasilkan lapisan tanah baki yang tebal berbanding kawasan sederhana panas dan gersang (Halim et al. 2022; Huat et al. 2008; Keng et al. 2020) dengan variasi zon luluhawa serta mempamerkan ciri-ciri yang kompleks (Abad et al. 2016; Jaques et al. 2021). Tanah baki merupakan asalan jasad batuan yang terluluhawa secara *in situ*, iaitu setempat (Duarte & Rodrigues 2018) tanpa melibatkan sebarang proses geomorfologi lain seperti pengangkutan atau pemendapan (Blight 2012). Selain pengaruh iklim, pembentukannya turut didorong oleh beberapa faktor utama lain meliputi komposisi kimia batuan asalan, keadaan persekitaran, masa, topografi, aktiviti mikrobiologi serta tahap kepesatan luluhawa (Aloni & Alexander 2020; Chen et al. 2023a; Huat, Toll & Prasad 2012).

Secara amnya, komposisi tanah baki terdiri daripada mineral, bahan organik, udara dan air di samping bahan aktif lain seperti pecahan karbonat dan bahan amorfus oksida/hidroksida (Wan Zuhairi & Nurita 2019). Mineral kuarza merupakan antara mineral primer yang kekal dalam tanah baki berpasir disebabkan sifat ketahanannya terhadap luluhawa yang tinggi (Wilson 2020). Penguraiannya bersama mineral silika yang lain (mika, feldspar, piroksen, amfibol) melalui tindak balas luluhawa kimia (proses hidrolisis) berterusan membentuk mineral sekunder seperti mineral lempung dan oksida besi/ hidroksida. Antara mineral lempung atau mineral filosilikat yang biasa ditemui di dalam tanah baki adalah seperti alofan, haloisit, kaolinit, ilit, and montmorilonit (Iqbal et al. 2021; Wesley 2010; Wilson 1999). Kehadiran mineral

lempung yang berbeza ini secara tidak langsung mempengaruhi sifat mekanikal tanah meliputi kebolehpayaan penjerapan air, tahap keplastikan dan kapasiti pengembangan (Kumari & Mohan 2021) selain menjadi faktor penyumbang kepada kebolehakisan tanah (Al-Shayea 2001; Ayoubi et al. 2022; Blattmann et al. 2019; Lehman et al. 2021; Ramezanpour et al. 2010). Kebolehakisan tanah yang tinggi menjadi pendorong kepada kejadian tanah runtuh janaan hujan di negara-negara beriklim tropika seperti Indonesia, Thailand, Sri Lanka, Vietnam, Filipina termasuklah Malaysia (Batumalai et al. 2023; Dechkamfoo et al. 2022; Do et al. 2022; Octaviarini et al. 2023; Talubo et al. 2015; Senanayake et al. 2022).

Proses hakisan tanah dicituskan oleh dua (2) proses utama iaitu penyerakan (Erenson 2023; Vakili et al. 2024) dan pengasingan (Ali & Sterk 2015; Kinnell 2021; Wang et al. 2023a) akibat tindakan daya luaran seperti air (Yu, Chen & Sun 2024). Serakan dalam tanah berlaku apabila ion natrium ( $\text{Na}^+$ ) terjerap pada permukaan lempung dan bertindak balas dengan air lalu mengakibatkan butiran lempung menolak dan menjauhi antara satu sama lain. Keadaan ini mengakibatkan pemisahan partikel lempung dengan cepat lalu mengurangkan tarikan kohesif (Abbaslou, Hadifard & Poorgohardi 2016) dan menggalakkan proses degradasi tanah (Sayehvand & Dehghani 2014), berbanding tanah lempung normal yang lebih rentan terhadap hakisan (Fell et al. 2013). Pengasingan adalah proses di mana butiran tanah terpisah di bawah pengaruh daya atau kuasa hidraulik. Oleh disebabkan sifatnya yang mudah terserak, tanah ini berupaya membentuk rekahan di permukaan lalu meningkatkan kebolehpayaan hakisan. Hakisan permukaan berlaku apabila hujan dan aliran permukaan memisahkan butiran tanah dan mendedahkan kawasan terdedah kepada degradasi tanah berlanjutan. Keadaan ini berbeza bagi hakisan dalaman di mana ianya melibatkan pemisahan butiran tanah oleh penyusupan air lalu membentuk rongga yang melemahkan keseluruhan struktur tanah.

Walau bagaimanapun, interaksi spesifik antara proses hakisan permukaan dan dalaman terutamanya dalam konteks rekahan tanah masih kurang difahami dan tidak di kaji dengan mendalam (Slimani, Boukhemacha & Marouf 2023). Ketidaktentuan ragam iklim dan kepesatan pembangunan memerlukan penyelidikan yang lebih mendalam berhubung mekanisme hakisan permukaan dan dalaman bagi menjelaskan interaksi ini dan implikasinya terhadap kestabilan dalaman tanah khususnya di kawasan cerun.

Keadaan iklim yang unik di Malaysia yang ditandai dengan hujan lebat dan kelembapan yang tinggi meningkatkan potensi hakisan terutamanya dengan kehadiran tanah terserak. Hubungan hidrodinamik tanah terserak dan kerentanannya terhadap hakisan permukaan dan dalaman perlu difahami bagi merangka langkah mitigasi bencana dan amalan pengurusan tanah yang mampan. Menangani cabaran ini secara holistik adalah penting untuk melindungi komuniti dan memastikan kelestarian infrastruktur pada masa hadapan.

## 1.2 PERMASALAHAN KAJIAN

Isu melibatkan tanah terserak kini telah mula mendapat perhatian di Malaysia. Garis Panduan Pengurusan Keselamatan Empangan Malaysia 2017 (MyDAMS) telah menekankan potensi masalah pembangunan struktur empangan di kawasan tanah terserak dan di mana penilaian kestabilan perlu dijalankan dengan teliti (Jabatan Pengairan dan Saliran Malaysia 2017). Penilaian Kepada Alam Sekeliling (EIA) yang dikeluarkan oleh Jabatan Alam Sekitar (2020) untuk Projek Laluan Rel Pantai Timur turut menggariskan bahawa penemuan lapisan tanah bermasalah (seperti lempung lembut) perlu diekskavasi sebelum ditambak semula sebagai tapak asas rel. Selain itu, Jabatan Pengairan dan Saliran (2010) turut memandangkan serius berhubung kewujudan tanah terserak dalam perancangan kawalan hakisan dan sedimen di tapak pembinaan. Hal ini menunjukkan bahawa kewujudan fenomena serakan dalam tanah berlempung menimbulkan cabaran yang signifikan dalam konteks kejuruteraan tanah. Kajian terdahulu telah membuktikan bahawa tanah terserak merosakkan struktur pondasaran bangunan, jalan raya, kegagalan empangan serta tanah runtuh (Fan 2017; Premkumar et al. 2016; Richards & Reddy 2007; Vakili et al. 2020; Wang, Yuan & Wang 2020), yang menimbulkan risiko yang besar kepada keselamatan awam, infrastruktur dan kestabilan ekonomi (Fatima et al. 2023). Hal ini berikutan kegagalan berasosiasi dengan tanah terserak adalah bersifat tiba-tiba, berbahaya dan sukar dirawat (Vakili et al. 2024).

Walau bagaimanapun, mekanisme hakisan oleh tanah terserak yang digariskan ini hanya melihat secara umum terhadap pembentukan hakisan paip bagi empangan akibat tindakan kapilari air mahupun sifat pengembangan-pengecutan yang dijana oleh tanah berlempung. Pemahaman ke atas interaksi hujan terhadap hakisan dalaman dan

hakisan biasa yang berlaku di permukaan melalui proses serakan dan pengasingan masih terhad menyebabkan zon-zon bermasalah tidak dapat dikesan dengan sempurna. Keadaan ini berupaya menyumbang kepada beberapa siri rantaian kejadian geobencana yang sukar ditafsir faktor pencetus kejadiannya akibat kegagalan dalam memahami canggaan struktur tanah yang berlaku di bahagian sub-permukaan. Melalui analisis makmal yang dirangka khusus bagi hakisan permukaan dan dalaman, mekanisme kedua-duanya dikaji dengan mendalam bagi memahami perbezaan morfometrik, kadar pengasingan dan ragam canggaan tanah terserak di Malaysia.

### 1.3 OBJEKTIF KAJIAN

Kajian ini merangkumi objektif-objektif seperti berikut:

- i. Menentukan sifat fiziko-kimia tanah dan jenis mineral lempung berdasarkan jenis tanah baki;
- ii. Menentukan tahap serakan tanah berdasarkan jenis mineral lempung dominan;
- iii. Mengukur morfometrik rekahan tanah mengikut tahap serakan; dan
- iv. Mengukur kadar pengasingan tanah bagi hakisan permukaan dan dalaman serta perkaitannya terhadap kejadian tanah runtuh janaan hujan.

### 1.4 PERSOALAN KAJIAN

Persoalan-persoalan yang dikemukakan dalam kajian adalah seperti berikut:

- i. Adakah terdapat perbezaan ciri-ciri sifat fiziko-kimia dan struktur mikro tanah lempung mengikut jenis tanah baki?;
- ii. Adakah terdapat perbezaan tahap serakan tanah lempung yang didominasi oleh mineral lempung yang berbeza?;
- iii. Bagaimanakah ciri-ciri morfometrik rekahan tanah lempung terserak dan tidak terserak?; dan
- iv. Adakah terdapat perbezaan kadar pengasingan tanah lempung terserak dan tidak terserak yang terhakis di permukaan dan dalaman yang mendorong kejadian tanah runtuh janaan hujan?

## 1.5 HIPOTESIS KAJIAN

Hipotesis-hipotesis kajian adalah seperti berikut:

- i. Tanah baki sedimen mempunyai peratusan butiran kohesif lebih tinggi dengan variasi mineral lempung berbanding tanah baki igneus dan metamorf yang mempengaruhi sifat fiziko-kimianya;
- ii. Lempung aktif seperti montmorilonit mempunyai tahap serakan yang lebih tinggi berbanding kaolinit;
- iii. Morfologi rekahan tanah terserak lebih seragam dan berintensiti tinggi berbanding tanah tidak terserak; dan
- iv. Hakisan dalaman mempunyai kadar pengasingan lebih tinggi berbanding hakisan permukaan yang didorong oleh proses penyerakan lalu membentuk zon lemah di bawah sub-permukaan tanah.

## 1.6 KEPENTINGAN KAJIAN

Kajian berhubung tanah terserak masih kurang dijalankan di Malaysia. Kajian mengenai sifat penyerakan dan pengasingan tanah baki sebagai mekanisme utama hakisan permukaan dan dalaman adalah relevan dengan iklim di kawasan tropika seperti Malaysia. Fenomena serakan tanah adalah sangat berkait rapat dengan kandungan kelembapan dan jenis mineralogi lempung yang mempengaruhi sifat kelakuan kejuruteraan tanah. Hasil kajian ini melalui penentuan sifat fiziko-kimia tanah dan simulasi makmal berdasarkan kuantifikasi morfometrik dan kadar pengasingan dapat dijadikan sebagai satu medium untuk para pengkaji memahami interaksi kompleks antara proses hakisan permukaan dan dalaman yang mempengaruhi kestabilan tanah.

Kajian ini boleh dijadikan sebagai panduan untuk merangka pelan pembangunan negara di mana kewujudan tanah terserak sebelum ini tidak di ambil kira walaupun isu melibatkan tanah terserak telah dilaporkan di seluruh dunia merentasi pelbagai jenis iklim. Walaupun Kerajaan Malaysia telah mengeluarkan beberapa garis panduan melibatkan pengurusan tanah bermasalah ini di tapak pembinaan dan empangan, pemahaman mengenai sifat, taburan dan kebolehakisan tanah ini masih terhad. Akhir sekali, kajian ini adalah selari dengan Matlamat Pembangunan Mampan (SDG) iaitu

Kehidupan Darat (SDG15) yang menekankan perlindungan dan pemuliharaan ekosistem daratan. Selain itu, di bawah matlamat Bandar dan Komuniti Mampan (SDG11), kajian dinamik proses hakisan dapat membantu dalam perancangan guna tanah kawasan membangun dan usaha mengurangkan risiko bencana. Melalui perangkaan pelan yang komprehensif, pihak berkepentingan seperti pemaju dan kerajaan dapat mengenal pasti kawasan berisiko tinggi untuk terserak selain merangka strategi pencegahan yang berkesan bagi melindungi infrastruktur dan komuniti daripada kejadian geobencana seperti tanah runtuh. Kajian ini juga selaras dengan matlamat Tindakan Memerangi Perubahan Iklim (SDG13) di mana ragam taburan hujan dan cuaca menyumbang kepada tindak balas kompleks di dalam tanah yang sentiasa berevolusi menyebabkan gangguan kepada kestabilan tanah secara keseluruhannya. Oleh itu, memahami ragam tindak balas yang berlaku di permukaan dan sub-permukaan membantu intervensi awal yang perlu dilakukan bagi mengelak sebarang potensi geobencana berskala besar.

## **1.7 STRUKTUR ORGANISASI TESIS**

Secara keseluruhannya, tesis ini mengandungi lapan (8) bab yang diperincikan secara komprehensif. Bab I merupakan pengenalan kepada kajian merangkumi pernyataan masalah, objektif kajian, persoalan kajian, hipotesis kajian dan kepentingan kajian. Bab II merupakan kajian literasi yang menekankan latar belakang dan konseptual skop kajian melalui sintesis kajian terdahulu seterusnya membawa kepada pengenalpastian jurang penyelidikan.

Bab III memberi fokus terhadap kaedah analitikal dan ekperimental yang digunakan untuk menilai sifat indeks tanah, sifat penyerakan tanah, pengukuran morfometrik rekahan dan kuantifikasi kadar pengasingan. Kaedah-kaedah ini merangkumi analisis fizikal, kimia dan simulasi berskala makmal. Bab IV pula mengupas keputusan dan perbincangan terhadap penilaian sifat indeks tanah baki yang terhasil daripada luluhawa tiga (3) jenis batuan induk utama: igneus, sedimen dan metamorf. Dapatan ini seterusnya membawa kepada pengelasan mineral lempung dominan yang wujud di dalam tanah seperti kaolinit, ilit, montmorilonit dan vermikulit. Bab V mempersembahkan dapatan data dan kupasan lanjut mengenai tahap serakan tanah berdasarkan jenis mineral lempung dominan. Variasi tahap serakan dalam tanah

lempung ini kemudian dikelaskan mengikut tahap serakan: terserak, sederhana terserak dan tidak terserak.

Bab VI merupakan pengukuran morfometrik rekahan seperti faktor intensiti rekahan (CIF) dan faktor ketumpatan rekahan (CDF) bagi melihat pengaruh serakan terhadap kereaktifan tanah dengan kehadiran mineral lempung yang berbeza. Bab VII pula akan mengupas dapatan kajian berhubung kadar pengasingan berlandaskan kepada dua (2) jenis eksperimen: simulasi flum dan ujian penyerakan lubang pin yang mewakili proses hakisan yang berbeza. Dapatan ini kemudian akan dikorelasikan secara statistik dengan parameter kajian seperti sifat fiziko-kimia dan serakan tanah bagi melihat perkaitannya terhadap mekanisme hakisan permukaan dan dalaman. Perbincangan secara kritikal juga dibuat bagi melihat interaksi antara hakisan permukaan dan dalaman terhadap kejadian tanah runtuh. Bab VIII adalah topik terakhir yang merumuskan secara holistik dapatan yang diperolehi mengikut objektif selain menggariskan hala tuju penyelidikan pada masa akan datang, terutamanya dalam konteks hakisan berasosiasi dengan tanah terserak.

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