# jurnal intelek

JULAI - DISEMBER 2003 • Bil. 1

UNIVERSITI TEKNOLOGI MARA
PERLIS

INFOREC

# JURNAL INTELEK 2003

**(Edisi 1 • Julai - Disember)**

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## PENGARAH KAMPUS UITM PERLIS

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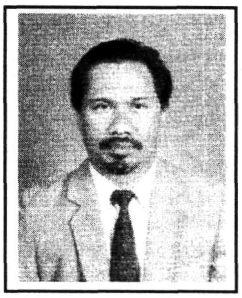

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# KERTAS KONSEP

# "RIM" CLASSIFICATION FOR PREDICTION OF SINKHOLE TRAGEDY IN LIMESTONE AREAS

**Roslan Zainal Abidin[1], Damanhuri Jamalludin[2], Mohd Fadzil Arshad[2] & Muklis Noordin[2]**
[1]National Soil Erosion Research Centre, UiTM Shah Alam, Selangor.
[2]Faculty Of Civil Engineering, UiTM Arau Campus, Perlis.

## ABSTRACT

*Sinkhole is a costly recurring problem faced by many countries such as Malaysia where some of the areas having limestone bedrock with underground cavities. This research is to establish the relationship between soil grading characteristics and occurrence of sinkholes.*

*Soil samples from sinkhole tragedy areas and areas where sinkholes were known to occur as well as areas where sinkholes are prone to occur, having limestone as the bedrock were taken and their grading characteristics identified.*

*From the results, it can be seen that a pattern on the soil grading characteristics can be categorised or classified in relation to the sinkhole tragedy areas as well as to other areas having a similar pattern. The category of classifying the degree of sinkhole occurrence was named as "RIM" Classification for Sinkhole Failure (after the name of researchers, Roslan, Damanhuri, Mohd. Fadhil & Mukhlis) can be used to indicate the risk level of potential sinkhole occurrences.*

*By using the "RIM" Classification, the prediction of sinkhole occurrences can easily be made by simply carrying out sieve tests to obtain the percentages of sand, silt and clay. These percentages are then compared with the "RIM" Classification to give an indication to the public as well as the government agencies on the degree of sinkhole occurrences on their land that can cause damage to their properties and lost of lives.*

## INTRODUCTION

Recently, sinkhole failure occurrences in Malaysia have become one of the major environment disasters. The recent sinkhole occurrences at Kem Oran, Perlis (Figures 1, 2 and 3) and Sg. Tapah, Ipoh, Perak (Figure 4) have become hot topic and focus of talk in the press. Most of the sinkholes occurred in areas having limestone with layers of cavities as the bedrock.

Sinkholes are formed as the result of a sudden collapse of the overlying soil into the cavity already existed in the limestone bedrock (Goodman, 1993). Thus depression with steep to sub vertical sides occurs with size varying in diameter as small as 0.5m to as large as 30m. The depth varies from 1m to 30m. Contributing factors include the rapid fluctuation of the water table due to heavy rain, extended period of drought and water withdrawal and also human activities that cause increase in infiltration (Mineral & Geosciences Department of Malaysia, 2000). However, in this study, investigation was carried out to determine the relationship between soil grading characteristics and occurrence of sinkhole failures.

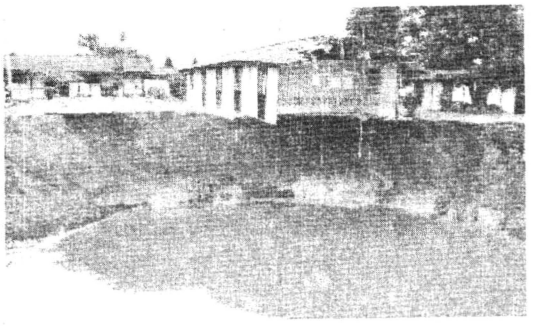

Figure 1. Part of damaged office building is hanging above a sinkhole at Kem Oran, Perlis.

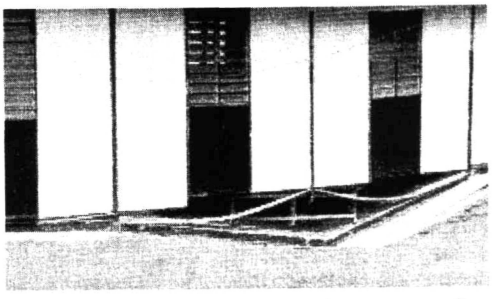

Figure 2. Excessive settlement occurred to concrete floor due to sinkhole at Kem Oran, Perlis.

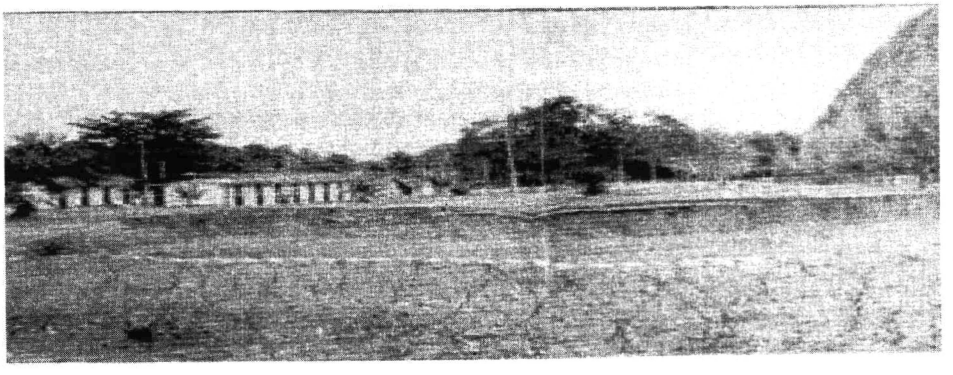

Figure 3. Road is badly damaged due to sinkhole at Kem Oran, Perlis

Figure 4. Badly damaged house due to sinkhole at Sungai Tapah, Ipoh, Perak.

## OBJECTIVE OF THE STUDY

The objective of the research is to determine whether there is a relationship between soil grading characteristics (% sand, % silt and % clay) and occurrence of sinkhole failures. This in turn will indicate the degree of sinkhole occurrences.

## RESEARCH METHODOLOGY

The methodology of this research is by analysing the physical properties of soil samples taken from 3 categories of sinkhole failure locations. The three categories of locations are:

i) Locations where sinkholes have occurred
ii) Locations where sinkholes were know to occur sometime ago (within 500 m from the failure sites)
iii) Locations where sinkholes are potential to occur with limestone as the bedrock. (Sinkhole generally occurs in areas with limestone as the bedrock)

Tables 1, 2 and 3 show the 3 categories of sites where soil samples were taken. Figure 5 shows the location of soil samples taken throughout Malaysian Peninsular. It also shows the limestone areas in Malaysia.

**Table 1. Soil samples taken at sinkhole tragedy sites - Category 1**

| Item | State | Location | Remark |
|---|---|---|---|
| 1 | Perlis | a) Kem Oran, Mata Air | Occurred On 14 October 2000 |
| 2 | Perak | a) Sg. Tapah, Manjoi, Ipoh | Occurred On 11 June 2001 |

**Table 2. Soil samples taken at sites where sinkholes were known to occur - Category 2**

| Item | State | Location | Remark |
|---|---|---|---|
| 1 | Perak | a) Buntong, Ipoh<br>b) Lahat, Ipoh<br>c) Ampangan, Ipoh<br>d) Masjid Jalan Dairi, Ipoh<br>e ) Gunung Rapat, Ipoh | |
| 2 | Selangor / Wilayah Persekutuan Kuala Lumpur | a) Jinjang, Selangor<br>b) Serdang, Selangor<br>c) The Mines, Selangor<br>d) Ampang, Selangor<br>e) Kg Dato Keramat Wilayah Persekutuan Kuala Lumpur | |

**Table 3. Soil samples taken at sites where sinkholes are potential to occur (Limestone as bedrock) - Category 3**

| Item | State | Location | Remark |
|---|---|---|---|
| 1 | Perlis | a) Taman Budaya, Kangar<br>b) Kangar Town | |
| 2 | Kedah | a) Gua Cerita, Langkawi | |
| 3 | Kelantan | a) Gua Musang, Railway Station<br>b) 1 Km From Gua Musang Town | |
| 4 | Pahang | a) Kg. Sg. Damar, Padang Tungku<br>b) Kg. Gua, Pdg. Tungku | |
| 5 | Selangor | a) Batu Caves, Selangor | |

The summary of the methodology adopted in this research includes :

i. Physical reconnaissance of the sinkhole failure areas.
ii. Soil sampling at various categories of sinkhole failure and limestone areas.
iii. Sieve tests were carried out and grading characteristics of the soil samples were plotted.

iv. Formulating "RIM" Classification for Sinkhole Failure Index (after the name of the researchers Roslan, Damanhuri, Mohd Fadzil & Mukhlis) in relation to sinkhole failure occurrences.
v Establishment of "RIM" Classification for degree of sinkhole occurrences.

Soil samples were taken about 0.3m below the ground surface. Figure 6 shows the typical soil sample taken at each site. Generally at each location, 3 soil samples were taken at about 10m apart. A total of 53 soil samples were collected. The locations of soil samples taken throughout the Malaysian Peninsular are shown in Figure 5. Soil classification i.e. Particles Size Distribution (PSD) comprising of sieve test analysis and hydrometer tests were carried out at the Soil Mechanic Laboratory, UiTM Arau Campus, Perlis. Both tests were carried out in accordance with Head (1980) and British Standard 1377: Part 2 (1990). By using the sieve analysis results from the soil report, the imputers (i.e. % sand, % silt & % clay contents) were used for the analysis (Roslan et. al. 2001). The gravel component of the soil samples was neglected when analysis was carried out.

## ANALYSIS OF RESULTS AND DISCUSSIONS

The maximum and minimum contents of sand, silt and clay for areas where sinkholes had occurred were taken as references. They are considered as category 1 sinkholes with HIGH degree of sinkhole occurrences. Category 2 sinkholes (with MODERATE degree of sinkhole occurrences) are the areas where sinkholes were known to occur sometime ago. Any of the soil samples from category 2 sinkholes that satisfy the maximum and minimum contents of sand, silt and clay of category 1 will be classified as category 1. If not, they will be in category 2. Category 3 sinkholes (with LOW degree of sinkhole occurrences) are the areas where sinkholes are potential to occur. The soil samples will be categories as category 2 if they satisfy the maximum and minimum sand, silt and clay contents for category 2. Otherwise, they will remain in category 3 (Roslan et. al. 2002). Based on these criteria, "RIM" Classification for sinkhole failure index is show in Table 4.

**Table 4: "RIM" Classification of sinkhole failure index**

| Sinkhole Category | Soil Grading Characteristic In Limestone Area | | | | | | Degree Of Sinkhole Occurrence |
|---|---|---|---|---|---|---|---|
| | Sand (%) | | Silt (%) | | Clay (%) | | |
| | Max. | Min. | Max. | Min. | Max. | Min. | |
| 1 | 89.60 | 63.60 | 30.96 | 7.40 | 12.23 | 0.00 | High |
| 2 | 62.00 | 9.72 | 45.51 | 8.60 | 62.99 | 0.00 | Moderate |
| 3 | 48.20 | 4.20 | 62.47 | 13.96 | 64.44 | 0.00 | Low |

Based on "RIM" Classification for sinkhole index, Tables 5, 6 and 7 show the sinkholes category 1, 2 and 3 respectively.

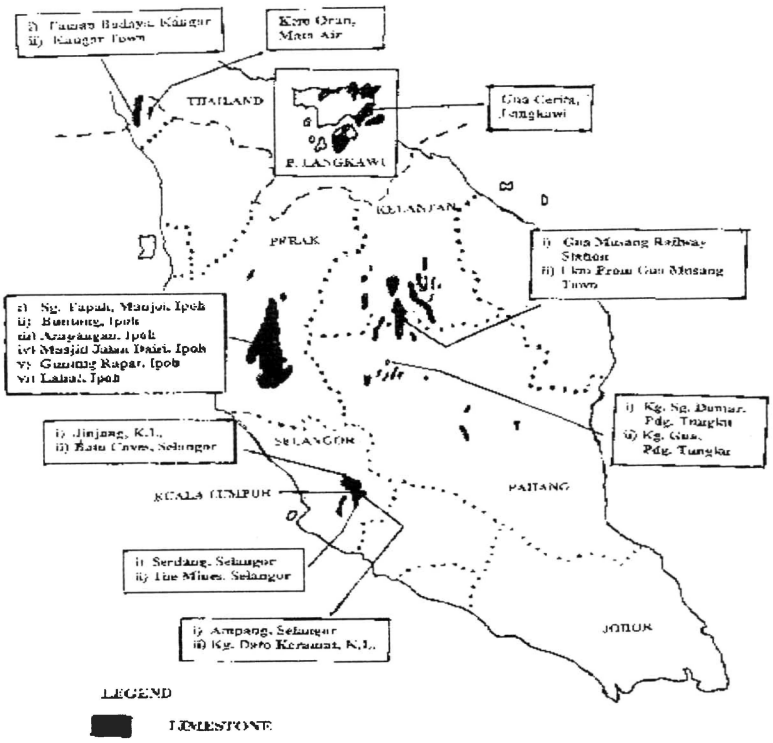


Figure 5. Locations of soil samples taken from sinkholes and limestone areas in Malaysia

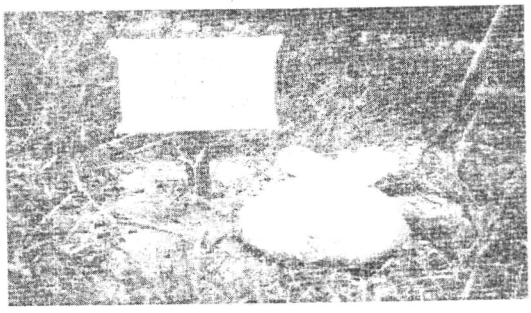

Figure 6. About 1 kg. of soil sample was taken from each site

**Table 5. "RIM" Classification for sinkhole Category 1 - with HIGH Degree of sinkhole occurrences**

| Item | Soil Sample | % Sand | % Silt | % Clay | Degree | State |
|---|---|---|---|---|---|---|
| 1 | Site 31 ( Gunung Rapat S 2 ) | 89.60 | 8.40 | 0.00 | High | Perak |
| 2 | Site 41 ( Ampang S 3 ) | 86.09 | 9.49 | 0.00 | High | Selangor |
| 3 | Site 25 ( Sg. Tapah S 3 ) | 85.08 | 7.44 | 0.00 | High | Perak |
| 4 | Site 24 ( Sg. Tapah S 2 ) | 82.60 | 7.40 | 0.00 | High | Perak |
| 5 | Site 28 ( Masjid Jalan Dairi S 2 ) | 78.80 | 7.50 | 0.00 | High | Perak |
| 6 | Site 32 ( Gunung Rapat S 3 ) | 78.70 | 11.44 | 2.86 | High | Perak |
| 7 | Site 23 ( Sg. Tapah S 1 ) | 76.81 | 14.53 | 0.00 | High | Perak |
| 8 | Site 40 ( Ampang S 2 ) | 74.50 | 15.40 | 0.00 | High | Selangor |
| 9 | Site 33 ( Buntung S 1 ) | 72.00 | 9.70 | 0.80 | High | Perak |
| 10 | Site 3 ( Kem Oran S3 ) | 68.20 | 28.43 | 3.37 | High | Perlis |
| 11 | Site 49 ( Serdang S 1 ) | 68.20 | 14.85 | 4.15 | High | Selangor |
| 12 | Site 34 ( Buntung S 2 ) | 68.2 | 12.21 | 4.49 | High | Perak |
| 13 | Site 2 ( Kem Oran S2 ) | 66.60 | 21.17 | 12.23 | High | Perlis |
| 14 | Site 48 ( Kg. Dato Keramat S 2 ) | 64.90 | 30.96 | 1.24 | High | Kuala Lumpur |
| 15 | Site 27 ( Masjid Jalan Dairi S 1 ) | 64.00 | 15.27 | 6.93 | High | Perak |
| 16 | Site 1 ( Kem Oran S1 ) | 63.60 | 26.25 | 7.35 | High | Perlis |

**Table 6. "RIM" Classification for sinkhole Category 2 - with MODERATE Degree of sinkhole occurrences**

| Item | Soil Sample | % Sand | % Silt | % Clay | Degree | State |
|---|---|---|---|---|---|---|
| 1 | Site 26 ( Ampangan S 1 ) | 62.00 | 15.60 | 10.60 | Moderate | Perak |
| 2 | Site 51 ( Serdang S 3 ) | 60.00 | 8.60 | 0.00 | Moderate | Selangor |
| 3 | Site 47 ( Kg. Dato Keramat S 1 ) | 59.96 | 19.03 | 0.00 | Moderate | Kuala Lumpur |
| 4 | Site 37 ( Lahat S 2 ) | 58.80 | 17.02 | 10.74 | Moderate | Perak |
| 5 | Site 46 ( Jinjang S 2 ) | 58.66 | 18.04 | 5.64 | Moderate | Selangor |
| 6 | Site 29 ( Masjid Jalan Dairi S 3 ) | 58.60 | 27.80 | 10.60 | Moderate | Perak |
| 7 | Site 38 ( Lahat S 3 ) | 57.65 | 14.51 | 21.39 | Moderate | Perak |
| 8 | Site 50 ( Serdang S 2 ) | 54.50 | 26.06 | 10.44 | Moderate | Selangor |
| 9 | Site 52 ( The Mines S 1 ) | 53.51 | 27.60 | 14.05 | Moderate | Kuala Lumpur |
| 10 | Site 53 ( The Mines S 2 ) | 51.02 | 17.29 | 9.37 | Moderate | Kuala Lumpur |
| 11 | Site 44 ( Batu Caves S 3 ) | 51.01 | 16.64 | 1.69 | Moderate | Selangor |
| 12 | Site 43 ( Batu Caves S 2 ) | 40.90 | 45.51 | 7.68 | Moderate | Selangor |
| 13 | Site 42 ( Batu Caves S 1 ) | 39.40 | 26.84 | 13.00 | Moderate | Selangor |
| 14 | Site 39 ( Ampang S 1 ) | 34.38 | 26.99 | 38.29 | Moderate | Selangor |
| 15 | Site 39 (Jinjang S 1 ) | 34.32 | 28.00 | 23.62 | Moderate | Selangor |
| 16 | Site 30 ( Gunung Rapat S 1 ) | 30.26 | 43.66 | 12.39 | Moderate | Perak |
| 17 | Site 36 (Lahat S 1 ) | 19.80 | 21.45 | 19.15 | Moderate | Perak |
| 18 | Site 35 ( Buntung S 3 ) | 9.72 | 26.69 | 62.99 | Moderate | Perak |

**Table 7. "RIM" Classification for sinkhole Category 3 - with LOW Degree of sinkhole occurrences**

| Item | Soil Sample | % Sand | % Silt | % Clay | Degree | State |
|---|---|---|---|---|---|---|
| 1 | Site 13 ( 1 Km From Gua Musang S 2 ) | 48.20 | 22.96 | 13.24 | Low | Kelantan |
| 2 | Site 19 ( Kg. Damar S 2 ) | 47.16 | 20.05 | 1.24 | Low | Pahang |
| 3 | Site 12 ( 1 Km From Gua Musang S 1 ) | 41.40 | 49.92 | 2.48 | Low | Kelantan |
| 4 | Site 22 ( Kg. Gua S 3 ) | 35.32 | 39.38 | 24.78 | Low | Pahang |
| 5 | Site 21 (Kg. Gua S 2 ) | 26.66 | 19.08 | 0.00 | Low | Pahang |
| 6 | Site 11 ( Gua Cerita S 3 ) | 18.80 | 62.47 | 18.73 | Low | Kedah |
| 7 | Site 10 ( Gua Cerita S 1 ) | 17.80 | 35.75 | 13.85 | Low | Kedah |
| 8 | Site 18 ( Kg. Damar S 1 ) | 16.16 | 31.04 | 47.92 | Low | Pahang |
| 9 | Site 17 (Gua Musang Railway Stn. S3) | 16.00 | 27.67 | 56.33 | Low | Kelantan |
| 10 | Site 16 (Gua Musang Railway Stn. S2) | 13.40 | 41.77 | 44.83 | Low | Kelantan |
| 11 | Site 20 ( Kg. Gua S 1 ) | 12.34 | 13.96 | 15.48 | Low | Pahang |
| 12 | Site 15 (Gua Musang Railway Stn. S1) | 9.20 | 26.36 | 64.44 | Low | Kelantan |
| 13 | Site 8 ( Taman Budaya S 2 ) | 9.15 | 40.26 | 26.52 | Low | Perlis |
| 14 | Site 14 ( 1 Km From Gua Musang S 3) | 7.28 | 54.96 | 23.84 | Low | Kelantan |
| 15 | Site 6 ( Kangar Town S 3 ) | 5.80 | 61.14 | 33.06 | Low | Perlis |
| 16 | Site 4 ( Kangar Town S 1 ) | 5.80 | 49.52 | 44.68 | Low | Perlis |
| 17 | Site 5 ( Kangar Town S 2 ) | 4.60 | 52.73 | 41.68 | Low | Perlis |
| 18 | Site 9 ( Taman Budaya S 3 ) | 4.60 | 33.75 | 61.17 | Low | Perlis |
| 19 | Site 7 ( Taman Budaya S 1 ) | 4.20 | 48.52 | 46.88 | Low | Perlis |

## CONCLUSIONS

From the study on sinkhole failures that was carried out, several conclusions could be derived based on the research data collected.

It can be seen clearly that by using " RIM" Classification method, high, medium and low risk of sinkhole occurrences can be tabulated as below.

| Sinkhole Category | Soil Grading Characteristic In Limestone Area | | | | | | Degree Of Sinkhole Occurrence |
|---|---|---|---|---|---|---|---|
| | Sand (%) | | Silt (%) | | Clay (%) | | |
| | Max. | Min. | Max. | Min. | Max. | Min. | |
| 1 | 89.60 | 63.60 | 30.96 | 7.40 | 12.23 | 0.00 | High |
| 2 | 62.00 | 9.72 | 45.51 | 8.60 | 62.99 | 0.00 | Moderate |
| 3 | 48.20 | 4.20 | 62.47 | 13.96 | 64.44 | 0.00 | Low |

As a conclusion, by using the "RIM" Classification method, the prediction of sinkhole occurrences in limestone areas can easily be made by carrying out sieve tests to obtain the percentages of sand, silt and clay. The percentages of sand, silt and clay are then compared with "RIM" Classification to give an indication to the public as well as the government agencies the degree of probability of sinkhole

occurrences on their land that can cause damage to their properties and lose of lives. Besides that, it is hoped that "RIM" Classification will not only give a great contribution to this nation but also to the international communities in realising the problematic issues related to sinkholes.

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