Influence of Relict Joints on Permeability of Residual Soil

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Abstract. Weathering process of granitic material results in the formation of relict joint in
lateritic layer of the weathering profile. The number and arrangements of the relict joints
affects the permeability of the residual soil which invariably affects water flow and suction
distribution in the residual soil. Although the permeability of residual soil without a relict joint
can be determined using standard permeability test, it is difficult to be measured when a relict
joint is incorporated due to limitation of size and area of the standard equipment. Hence,
modified permeability test equipment is introduced in this study. Two arrangement of the relict
joint in the equipment were considered. In the first arrangement one relict joint with various
spacing were tested while the orientation and spacing of the relict joint were tested using two
relict joints in the second arrangement. The results obtained shows that the permeability of the
residual soil due to one and two relict joint varies by two orders of magnitude. Therefore, the
number and spacing of relict joints modified the permeability of residual soil.

Keywords: Weathering, relict joint, residual soil.

1. Introduction
A landslide in residual soil normally occurs during or immediately after heavy rainfall. Previous
studies have shown that rainfall infiltration increases the soil water content which decreases matric
suction and hence decreases the additional shear strength provided by the matric suction which results
in landslides [1–4]. One of the factors that contribute to this phenomena is heterogeneity in the
residual soil which greatly affects the permeability of the soil [3]. Residual soil is the final product of
in-situ weathering process whether mechanical or chemical weathering of rock. This weathering
process alters the characteristics and behaviour of the parent rock, and results in successive layers of
weathering profile classified as Grade I to Grade VI according to six fold of weathering classification
of International Society for Rock Mechanics (ISRM) [5]. The weathering process involves in the
formation of residual soil introduces variation at material scale and also at field scale. At material
scale, the weathering process causes the decomposition of the rock to Grade VI (lateritic layer) and
Grade V (saprolitic layer). Therefore it introduces heterogeneity in the soil mass. These heterogeneity
includes variations in grain size, porosity, mineralogy, lithologic texture, rock mechanical properties,
structure and diagenetic processes [6, 7]. The heterogeneity of residual soil at field scales is due to
discontinuities such as joint, fault and fold and it is more significant in saprolitic layer.
Furthermore, since permeability is a function of grain size distribution [8], the lateritic layer have less permeability compare to saprolitic layer, as a result. The difference in permeability between these two layers is more pronounced when relict joint appears in the saprolitic layer. Kassim et al. [3] have proven that increasing the number of relict joint, increases the permeability of the soil.

Previous studies such as [9-11] have shown that a relationship exist between soil discontinuity and suction distribution in residual soil. The existing of relict joint greatly influence the permeability of soil which results in changes in suction distribution during rainfall. The relict joint can prevent or allowed more water to infiltrate into deeper soil profile depending on its orientation and arrangement. Usually, the relict joints exist in two or three vertical to subvertical joint sets in residual soil. However, based on the previous studies, only few studies were performed on permeability of residual soil with more than one relict joint. Therefore, this paper compares the permeability of residual soil with one relict joint and the effect of relict joint orientation using two relict joints.

2. Methodology

The soil used in this study was collected from Balai Cerap, which is a sloping site located within the campus of Universiti Teknologi Malaysia, Johor Bahru. Modified permeability test was performed to study the effect of relict joint on permeability of saprolitic layer. Figure 1 shows the modified permeability equipment.

![Figure 1. Modified permeability equipment.](image)

The modified permeability tests conducted were performed according to the procedure outlined in [12], using an equipment as shown in Figure 1. This equipment was made from steel frame and acrylic sheet sidewalls. The artificial relict joints were formed using 1 mm aluminium sheet at difference spacing. As shown in Figure 2, only vertical orientation with various spacing was considered for one relict joint. A relict joint with the spacing of 50 mm, 100 mm, 150 mm, 200 mm, 250 mm, 350 mm, 400 mm and 450 mm were tested. However, for two relict joints, the orientations were vertical and slightly inclined at approximately 6°. Similarly, a spacing 100 mm, 150 mm, 200 mm, 250 mm, 300 mm, 350 mm, 400 mm and 450 mm were also tested. The soil was compacted according to soil density recorded at site. A 25 mm thick layer of gravel was placed at the bottom and upper part of sample.
3.1 Calibration of Modified Permeability Equipment

Prior to the actual testing, the modified permeability apparatus was calibrated to determine the accuracy of the results obtained. The calibration was performed by conducting parallel permeability tests with standard and modified permeability equipment and comparing the results. The samples with same density were prepared and homogeneous soils without any relict joint were used for both tests.

3. Results and discussion

The soil collected from the site was divided into two major groups, sample obtained from 0 m to 0.5 m which is fully decomposed was considered as Grade VI soil, while other sample collected below 0.5 m were considered as Grade V. As mentioned earlier, the relict joint only appears in saprolitic layer which is Grade V layer. Thus, the soil sample was prepared according to Grade V properties.

The particles size distribution of the grade V shows that it possessed 48% gravel, 15% sand and the remaining 37% constitute the fine particle content. This soil was classified as silty gravel of high plasticity (GMH) according to British Soil Classification System (BSCS). The in-situ density and saturated permeability (ksat) tests shows that the soil possessed a density and permeability of 1805 kg/m³ and 3.68 x 10⁻⁶ m/s, respectively. The ksat of the soil obtained using modified permeability test is 4.52 x 10⁻⁶ m/s which indicate a difference of 23%.

Figure 3 shows the results of permeability test for one relict joint and two relicts joint. From this Figure, the permeability of soil with two relicts joint is higher than that of one relict joint. The variation in the permeability for the two relicts joint is almost in two orders of magnitudes which conformed to the previous findings by [5]. Similarly, the variation in the permeability due to the arrangements of the relict joint diminishes when the spacing increases. Furthermore, increasing the spacing between the relict joints indicates the samples almost replicate the homogeneous soil hence the permeability remained the same [3].
The permeability due to 1 and 2 relict joints are shown in Figure 4 and Figure 5, respectively. From both Figures the variation in the permeability can be divided into three parts. The curve starts with horizontal line then linear curve and finally ends with horizontal line.

For one relict joint, Part 1 is for spacing less than 100 mm, Part 2 for spacing greater than 100 mm but less than 300 mm and Part 3 for spacing greater than 300 mm. However, for two relict joint, Part 1 for spacing less than 200 mm, Part 2 for spacing greater than 200 mm but less than 350 mm and finally Part 3 for spacing greater than 350 mm. These results confirmed that, relict joint has significant effect on permeability of residual soil. The ksat of grade V (silty gravel) was clearly exhibited in Part 2 of the curve. Within this region an inverse relationship between permeability and spacing is observed which may largely contribute to the behaviours of the residual soil.
4. Conclusion
The permeability of weathered granitic material varies significantly due to the effect of relict joint. This variation may occur in various order of magnitude depending on the orientation and spacing of the joints. These variations can be summarized as follows:

1. The weathering grade varies with depth. The trend of variation results in different soil properties which are difficult to measure using laboratory testing.
2. Modified permeability test is one method that can be used and determine the permeability of soil with discontinuity.
3. In Grade V layer, the presence of relict joint affects the permeability of the soil. By increasing the number of relict joint in vertical direction seems as increasing the permeability of the soil.
4. For 1 relict joint, spacing between 100 mm to 300 mm may control the permeability of the residual soil. However, for 2 relict joint the permeability is affected with the spacing between 200 mm to 350 mm.

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