ENGINEERING CHARACTERISTICS OF KALO MATO ORGANIC SOIL FROM KATHMANDU

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INTISARI

Makalah ini memuat hasil penelitian terhadap tanah lempung organik yang banyak terdapat di Lembah Kathmandu, Nepal. Tanah yang dikenal dengan nama lokal Kalo Mato ('tanah hitam') bersifat sangat lunak sehingga menimbulkan persoalan bagi pembangunan di daerah tersebut. Penelitian diadakan terhadap contoh tanah yang diperoleh dari empat lokasi di Kathmandu, yaitu di Kopundole, Kalimati, Kirtipur dan Pulchowk. Kedalaman lubang bor bervariasi antara 10 m dan 30 m.

Hasil-hasil pengujian tanah menunjukkan bahwa Kalo Mato dari lokasi pemboran mempunyai kadar organik yang berkisar antara 4% dan 13%. Kandungan organic dalam tanah mempengaruhi besaran indeks dan sifat konsolidasi tanah. Kadar air, batas cair, kadar pori dan indeks kompresi meningkat dengan meningkatnya kadar organik, sedangkan specific gravity dan berat unit tanah turun dengan meningkatnya kandungan organik dalam tanah.

Pengujian konsolidasi jangka panjang menunjukkan kurva penurunan dengan waktu dalam skala logaritma yang berbeda dengan yang biasa dilihat dari hasil pengujian tanah non-organik, yaitu tidak jelasnya bagian dari kurva yang menunjukkan bagian dari konsolidasi primer dan sekunder. Dari bentuk kurva dapat disimpulkna bahwa cara yang biasa dilakukan untuk menentukan parameter konsolidasi berdasarkan Casagrande sebaiknya tidak diterapkan unruk maksud tersebut pada tranah Kalo Mato.

Introduction

Kathmandu Valley is located in the central part of Nepal, stretching 30 km in east west and 25 km in north-south directions, covering an area of about 650 square kilometers. The soil within the Valley comprises of lake sediment accumulated due to the damming of Bagmati River system as a result of the rise of the Mahabharat Range. The unconsolidated fine lacustrine deposit of silt and clay size particles is often interspersed with sand and gravel layers deposited by the rivers crisscrossing through the Valley floor at different

periods of time. The depth of the deposit above the bedrock varies within the Valley and reaches up to 550m roughly at the center of the city of Kathmandu (Katel, et al, 1996).

Of particular interest from geotechnical engineering point of view is the large presence of organic soils in Kathmandu, locally known as Kalo Mato. The name, which literally means black soil, is derived from its colour, which is dark grey to black. The soil was formed through the deposition in the ancient lake of the soil particles together with the organic colloids originating from decaying plants and other organism. The occasional encounter of decayed organic substance and outburst of gas during drilling as well as the strong odour are some of the evidences of the organic nature of the soil. House builders in Kathmandu dread the finding of Kalo Mato because of its very soft nature. To make matter worst, the soil is often found at a shallow depth where footings are normally placed. No attempt has so far been done to map the extent of Kalo Mato in Kathmandu, but from the borehole data collected from different sites the soil is it evident that the soil is found almost in the entire Valley, though the depth and thickness vary from location to location. In Thapathali, Sano Thimi and Bhaktapur, for instance, the upper surface of Kalo Mato has been discovered to start at a depth of 1 m while in Kalimati, Balkhu, Tahachal and Gyaneshwor it starts at around 5 m depth. In Pulchowk and Ratna Park it has been found to start at depths between 10 to 12 m.   The thickness of the layer has been found to vary from 1 m in Maharajgunj to more than 20 m in Thapathali.

An attempt to study the engineering characteristics of Kalo Mato in a systematic manner has been conducted by the Institute of Engineering (IOE) through the thesis work of students of the MSc. program in Geotechnical Engineering, starting in 2004. The research work comprised of the drilling of boreholes and sampling in Kopundole, Kalimati, Kirtipur and Pulchowk. Laboratory tests on disturbed and undisturbed samples collected from the sites. These studies were aimed at studying the variation of the soil properties with depth, and included the organic content, index properties, compressibility and strength characteristics. Data from previous soil investigations on Kalo Mato in other sites conducted by Central Material Testing Laboratory (CMTL) of IOE were incorporated in the study.

Drilling and description of Soil Samples

For the collection of samples in Kopundole, one borehole at the bank of Bagmati River near the Bagmati Bridge was drilled to a depth of 10 m. Drilling in Kalimati was part of a soil investigation for the construction of Head Office Building of Civil Saving and Credit Cooperative Ltd. in Soaltee Mod. Three boreholes up to 30 m depth each were drilled for the soil investigation project but samples from only one borehole were used for the research. Samples from Kirtipur were collected from a borehole drilled to 10 m depth in conjunction with soil investigation work for the construction of building belonging to the Central Department of Rural Development, Tribhuvan University. Those from Pulchowk were obtained from three boreholes drilled in the Engineering Campus to depth of 15 m. In Kopundole, Kalimati and Pulchowk drilling was performed by a mechanical auger using a truck-mounted drilling machine while in Kirtipur percussion drilling was done with Dando drilling machine.

Disturbed samples were collected at depth intervals of 1.5 m while the undisturbed samples were collected from intervals of about 1 m in Kopundole, 1,5 m in Kirtipur and 3 m in Kalimati. Disturbed samples were wrapped in thick plastic bags while the undisturbed samples were collected using tube having 106 mm internal diameter and 460 mm length. All sampling tubes were properly kept in the laboratory to prevent loss of moisture during the entire research period.

Testing Program

Samples taken from the different depths were tested to determine the organic content, index properties, compressibility and strength. The organic content was determined using loss on ignition method following the procedure described by ASTM D-2974. The samples were first oven dried at 105° C for 24 hours, then after transferred to a muffle furnace after weighing. The furnace temperature was increased gradually until 440° C where it was left constant for 24 hours. The weight of the organic matter is the difference between the oven dried weight and the final weight after heating in the muffle

furnace. The organic content is the ratio of the weight of organic matter and that of the dry soil, expressed in percentage.

General Nature of the Soil

The soil profiles obtained from the test results from Kopundole, Kalimati, Kirtipur and Pulchowk are presented in Figs.1 to 4, respectively. In all the sites the presence of 'Kalo Mato' was noticeable by the dark grey to black colour of the soil. In Kopundole, Kalimati and Kirtipur, Kalo Mato was found between 2 m depth till the final depths of the boreholes, while in Pulchowk it existed from 6 m depth till the end of the borehole at 10 m. The organic content in all the sites combined were between 4% and 13%, with the lowest range found in Kirtipur while the highest in Kopundole. The soils roughly fell in "Medium Organic Soil" category designated by the Swedish Geotechnical Classification System for organic content between 6% and 20% (Karlsson and Hansbo, 1981). NAVAC DM 7.01 (1981) classified soils with organic content between 5% and 30% as "Organic Soil". Table 1 shows the range of soil properties of Kalo Mato obtained from the four sites. The values of the Liquid Limit and Plasticity Index were taken from samples tested at natural condition, i.e., without oven drying. The values revealed the typical characteristics of organic soils in comparison to those of inorganic soils, namely low specific gravity and density, high water content, liquid limit, void ratio and compression index.

Table 1. Soil Properties of Kalo Mato from the Four Study Areas

| Soil Properties	Kopundole	Kirtipur	Kalimati	Pulchowk
Organic content,%	8.3 - 13.1	4.4 - 8.8	6.0 - 12.1	7.5 – 11.5
Specific gravity	2.29 - 2.33	2.38 - 2.55	2.41 - 2.60	2.25 – 2.45
Water content, %	95 – 145	80 - 107	40 - 89	81 – 115
Liquid limit, %	98 – 130	60 - 81	70 - 125	95 – 140
Plasticity Index, %	33 – 50	30 - 39	25 - 64	40 – 49
Bulk density, g/cm^3	1.30 - 1.50	1.40 - 1.50	1.42 - 1.60	1.45 - 1.52
Dry density, g/cm^3	0.50 - 1.0	0.70- 0.85	0.80 - 0.95	0.67 - 0.78
Void ratio	2.5 - 2.7	2.0 - 2.6	1.0 - 2.3	2.5 - 2.8
Compression index	1.05 – 1.20	0.86 - 1.23	0.49 -1.20	1.08 - 1.30
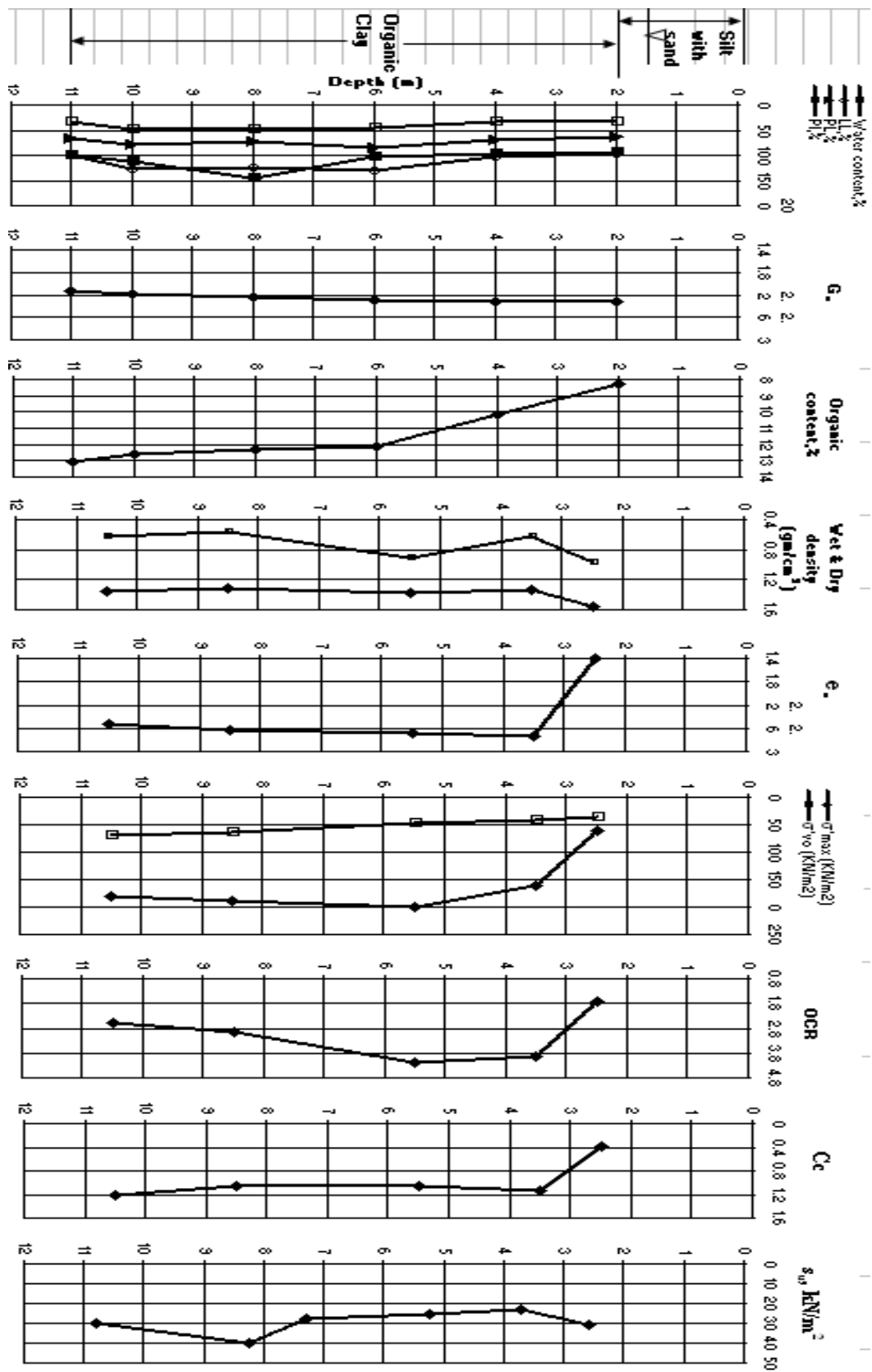
Fig. 1 Soil Profile from the Drilling Site at Kopundole
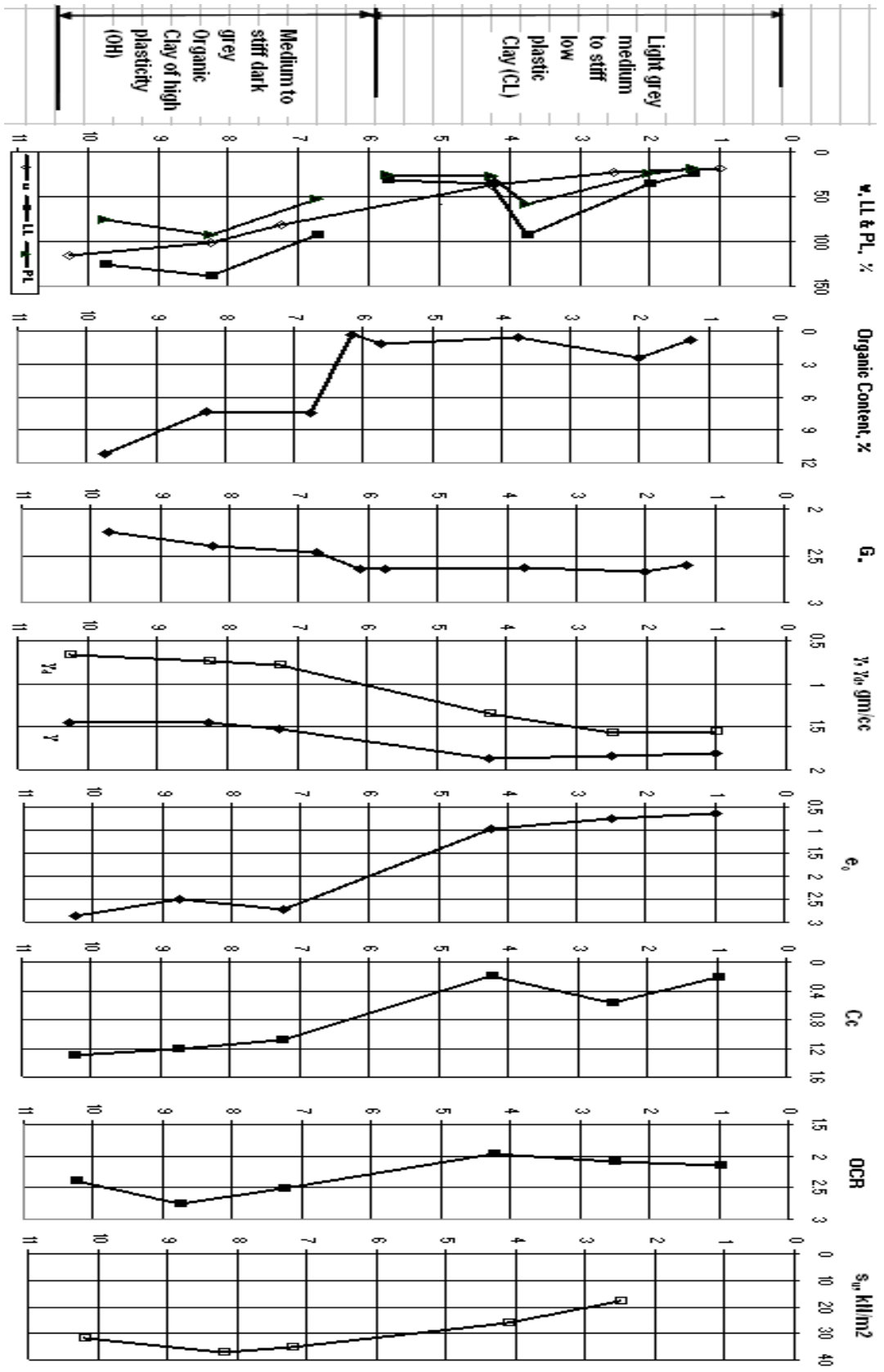
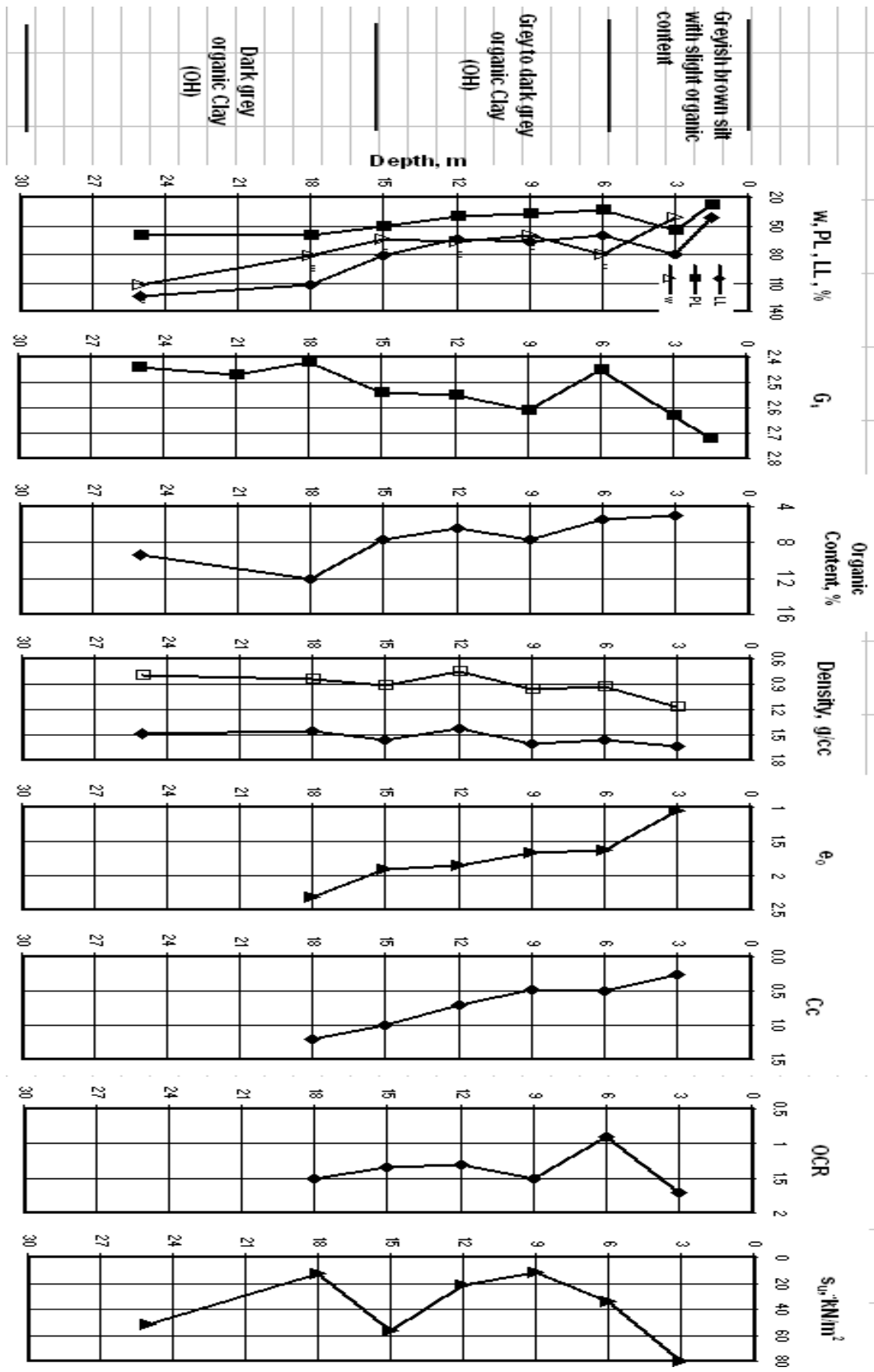Fig. 2 Soil Profile from Drilling Site at Pulchowk

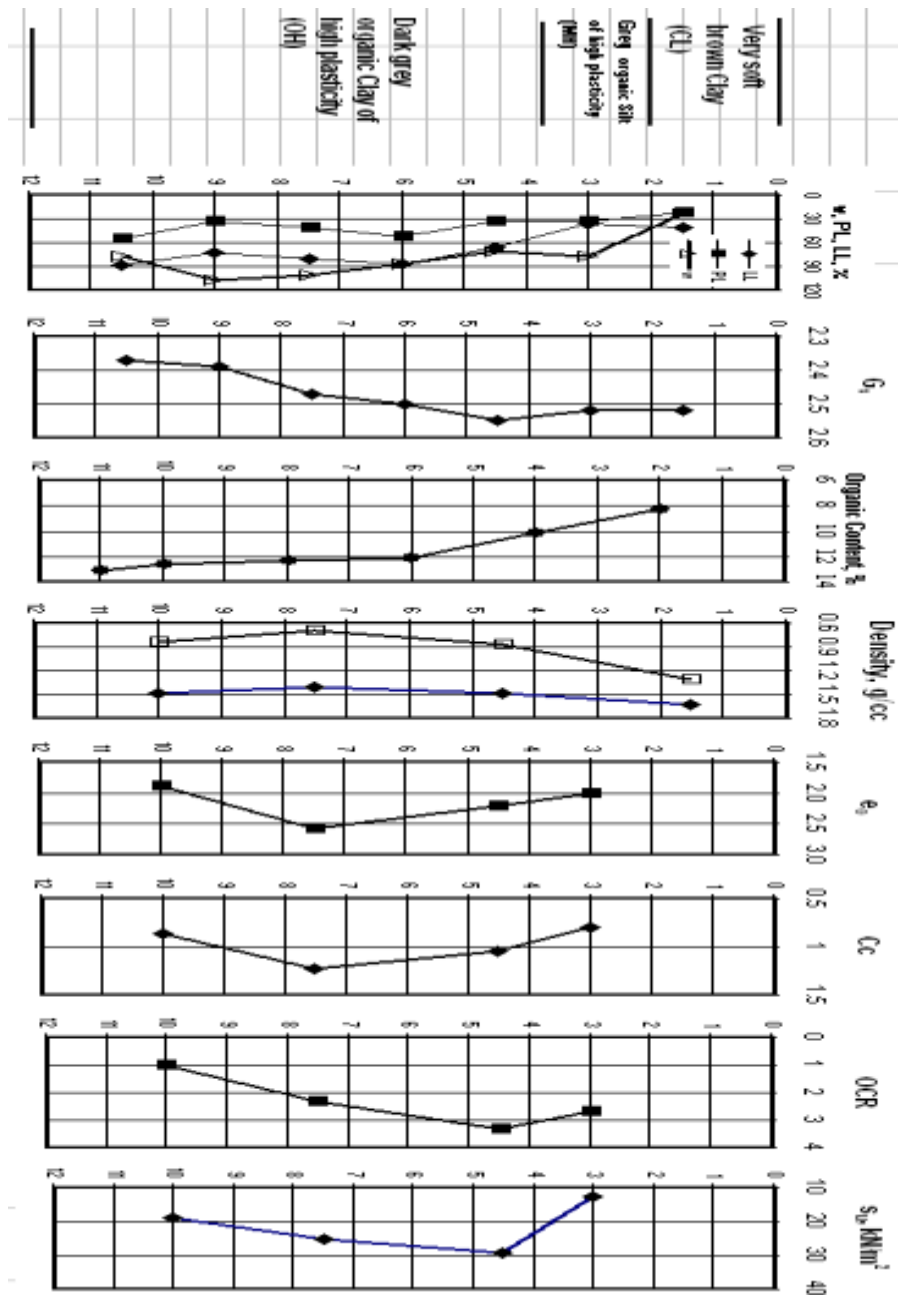Fig. 3 Soil Profile from Drilling Site at Kalimati

Fig. 4 Soil Profile from Drilling Site at Kirtipur

Figures 1 to 4 reveal that in the four drilling sites the organic content generally increased with depth. Such pattern has been also been reported in some drilling sites in Sweden though in other parts of the country the opposite pattern has been observed (Larsson, 1990). The figures show more or less similar pattern on how the soil properties varied with depth. Specific gravity, bulk density and dry density generally decreased with depth while water content, Atterberg limits, in-situ void ratio and compression index increased with depth. These patterns seemed to be related to the increase of the amount of organic content with depth, which led to the conclusion that increasing organic content in

the soil caused decrease in specific gravity and density while at the same time it caused increase in water content, Atterberg limits, void ratio and compression index. In an earlier paper on Kalo Mato (Handali et all, 2007), it was shown that relationships between the organic content and the soil properties were more or less linear.

Compressibility

Several series of oedometer tests were performed on undisturbed samples taken from the boreholes at depth intervals of roughly 3 m from the four study-areas mentioned above. The tests were mostly conducted on Kalo Mato samples though several samples with low organic content retrieved from the boreholes were also subjected to the same test, such as the sample from Kopundole at 2.5 m depth and those taken from depths of 1.0 m, 2.25 m and 4.25 m at Pulchowk site. The e-log σ_v curves for all the samples are shown in Figs. 5. Most of the Kalo Mato soil samples showed compression indices above 1.0, except for the samples taken from Kalimati between 6 m and 12 m depth where the compression index was found between 0.5 and 0.6. At deeper depths, though, the compression index increased to values between 1.0 and 1.2. The highest compression index was 1.3, found at Pulchowk at 10 m depth.
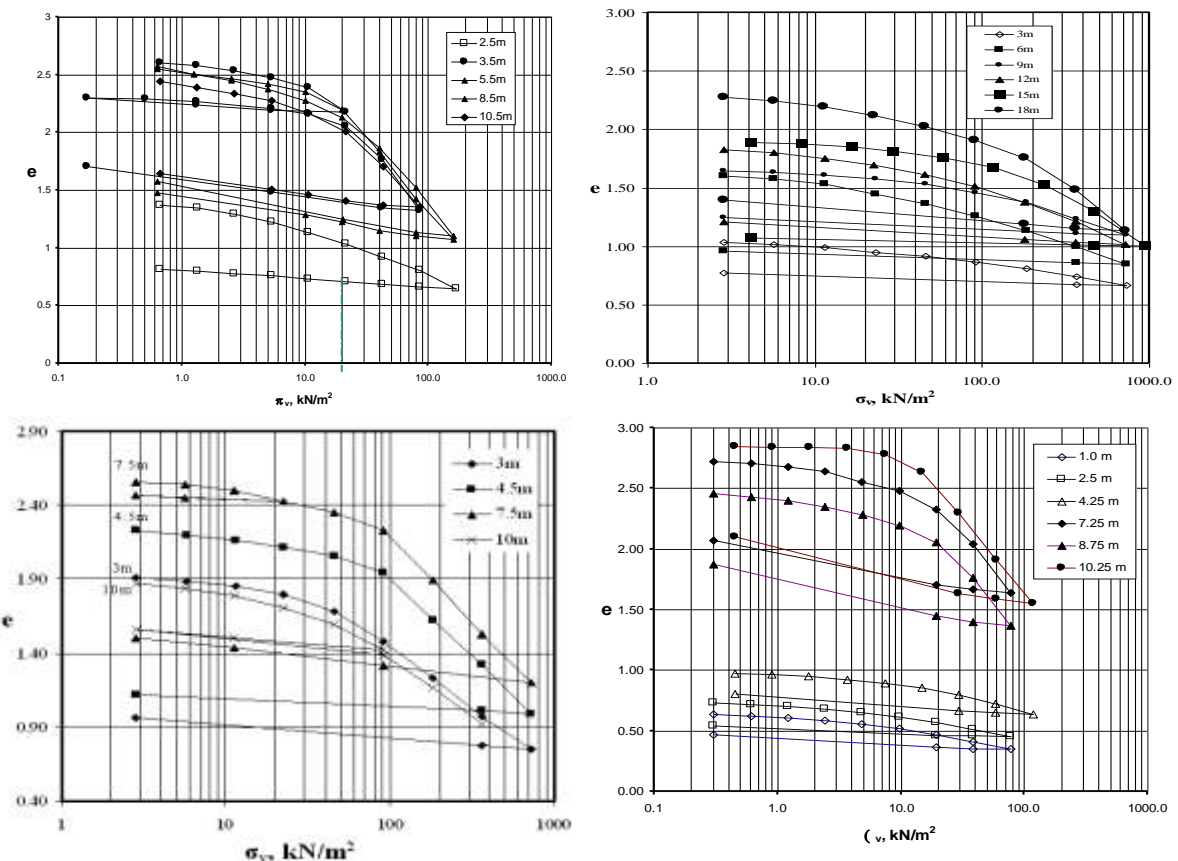

Note: Graphs for Kalo Mato are denoted in solid symbols

Fig. 5   Consolidation Test Results from Kopundole (a), Kalimati (b), Kirtipur (c) and Pulchowk (d).

Long-term Settlement

Two undisturbed Kalomato samples were subjected to long-term loading to observe their secondary compression characteristics from 1-D consolidation test. The sample was taken from Kalimati at 6 m depth while another sample was from Kopundole at 10.5 m depth. The dimension of the sample from Kalimati was 75 mm in diameter and 20.0 mm in thickness, while the one from Kopundole was trimmed to 60 mm diameter and 18.80 mm thickness. The sample from Kalimati was subjected to gradual increase of pressure from zero to 180.42 kN/m^2 at a load increment ratio of 2, and then brought to a final pressure of 360.95 kN/m^2 after an interval of 48 hours. The sample from Kopundole was subjected to the same fashion of loading up to 287.14 kN/m^2 before it was subjected to the final load of 430 kN/m^2. The final load was kept on the sample from Kalimati until day 163 while for the Kopundole sample it was kept until day 194. The final pressures kept on the samples were significantly higher than their maximum past pressures to ensure that compression occurred in normally consolidated states. The samples were kept inundated with water at all time.

The settlement – log time graph of the sample from Kalimati is shown in Fig. 6. It can be observed that the graph behaved differently from the typical shape expected to occur in most clays, namely an initial convex curve followed by a linear line signifying primary consolidation, then a concave curvature denoting the transition into secondary compression, and finally a long straight line, signifying secondary consolidation. The graph in Fig, 6 shows an apparent transition from primary consolidation to secondary consolidation mildly occurring at just 8 minutes after loading initiated. This was followed by a long straight line which occurred up to 60,000 minutes (roughly 42 days). The part of the curve could be interpreted as 'secondary compression' in the normal interpretation of consolidation test data. The problem of interpreting the test data in the above manner is that primary consolidation was over in just 8 minutes. This was hardly possible considering the thickness of the soil sample and the fine grained nature of the soil.

The assumption that the transition between primary and secondary consolidation occurred at minute 8 will also raise a problem in interpreting the rest of the curve. As explained in the following paragraph.
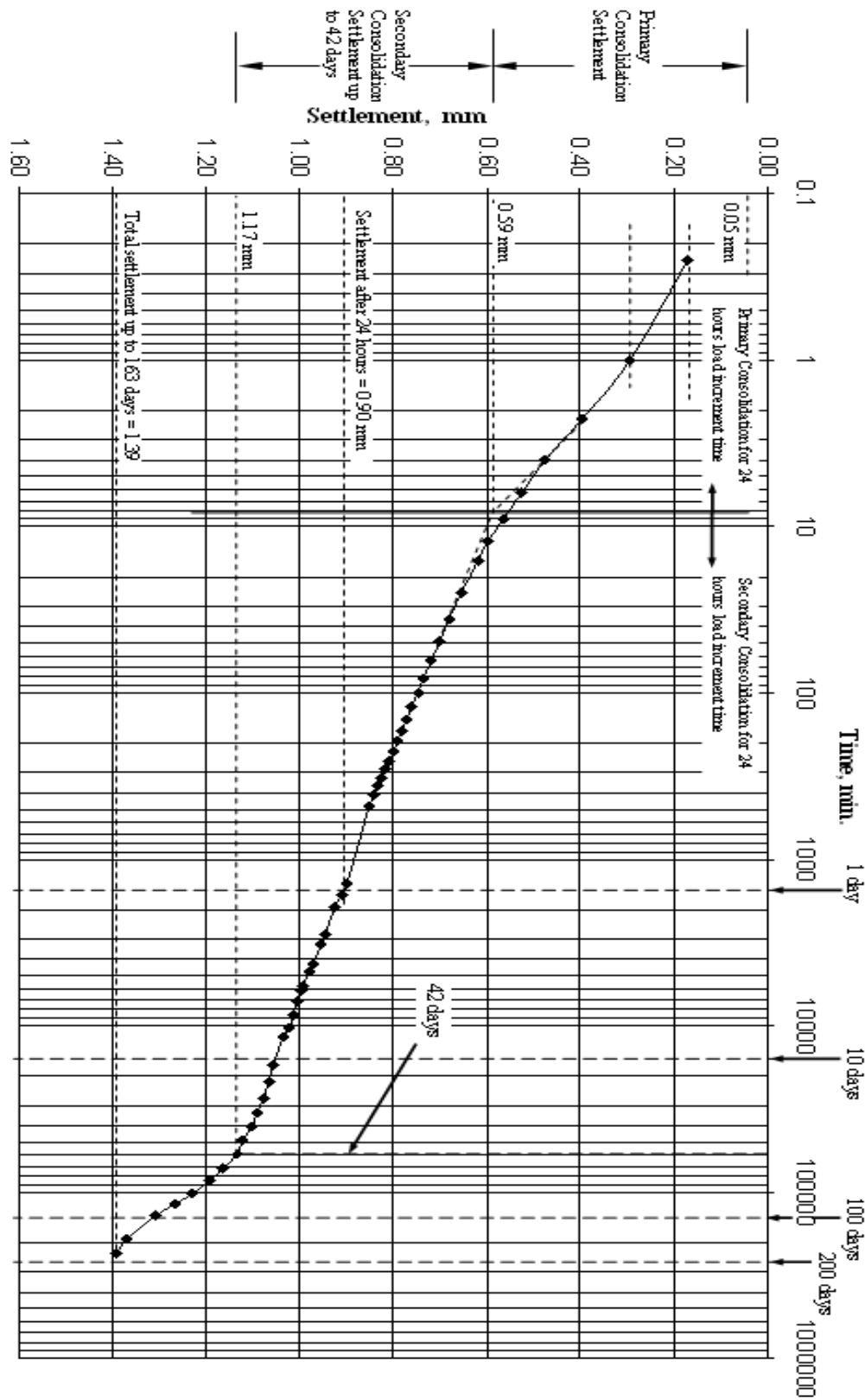
Fig. 6 Long-term Settlement Curve from Undisturbed Sample Taken from Kalimati Drilling Site at 6 m Depth and A Possible Interpretation of Primary and Secondary Consolidation Processes (Time in Log Scale)

At minute 60,000 the linear line that was supposed to be the secondary compression line turned downward to become another linear line with higher tangent than the earlier part of the graph. If the earlier part of the graph was indeed that of secondary compression, the line should continue with the same slope with the progress of time. This trend has been an accepted fact led to the widely used formula of calculating secondary settlement with respect to time, based on the slope of the secondary compression linear line in the settlement-log time plot. Should the formula be used to calculate secondary settlement for Kalo Mato using the slope of the 'secondary compression line' in Fig. 6, the result would be an underestimation of the real settlement. it will lead to an underestimation, because the settlement which occurred between 60,000 and 235,000 minutes (day 163) would not be included in the calculation. The fact that the curve turned downward at minute 60,000 meant that the linear portion before that should not be interpreted as the secondary compression line. The same situation could be observed in Fig. 7 showing the long term settlement of the sample from Kopundole.

The sample from Kopundole depicted a more or less linear relationship between the first 10 and 20,000 minutes (day 14) duration of the test. Unlike the sample from Kalimati, the sample from Kopundole did not display seemingly early transition from primary to secondary consolidation. The curve continued on a straight line path at more or less the same slope until minute 20,000 (day 83). Beyond that the settlement curve turned downward into a steeper linear line up to minute 120,000 (day 83). This trend was similar to that observed in the sample from Kalimati at minute 60,000. The linear curve in Fig. 7 was then followed by a milder straight line till the end of loading at around 280,000 minutes (day 194).

At a glance the curve appeared to resemble the normal settlement – log time curve with minute 120,000 as the end of primary consolidation. The length of time for the sample to reach that state, however, made it hard to conclude that the end of primary consolidation occurred at that particular point. It appears that the conventional Casagrande method to distinguish primary and secondary consolidations using settlement-log time plot may not be the proper method for Kalo Mato. This also means that the determination of the coefficient of consolidation should be determine using a different method.
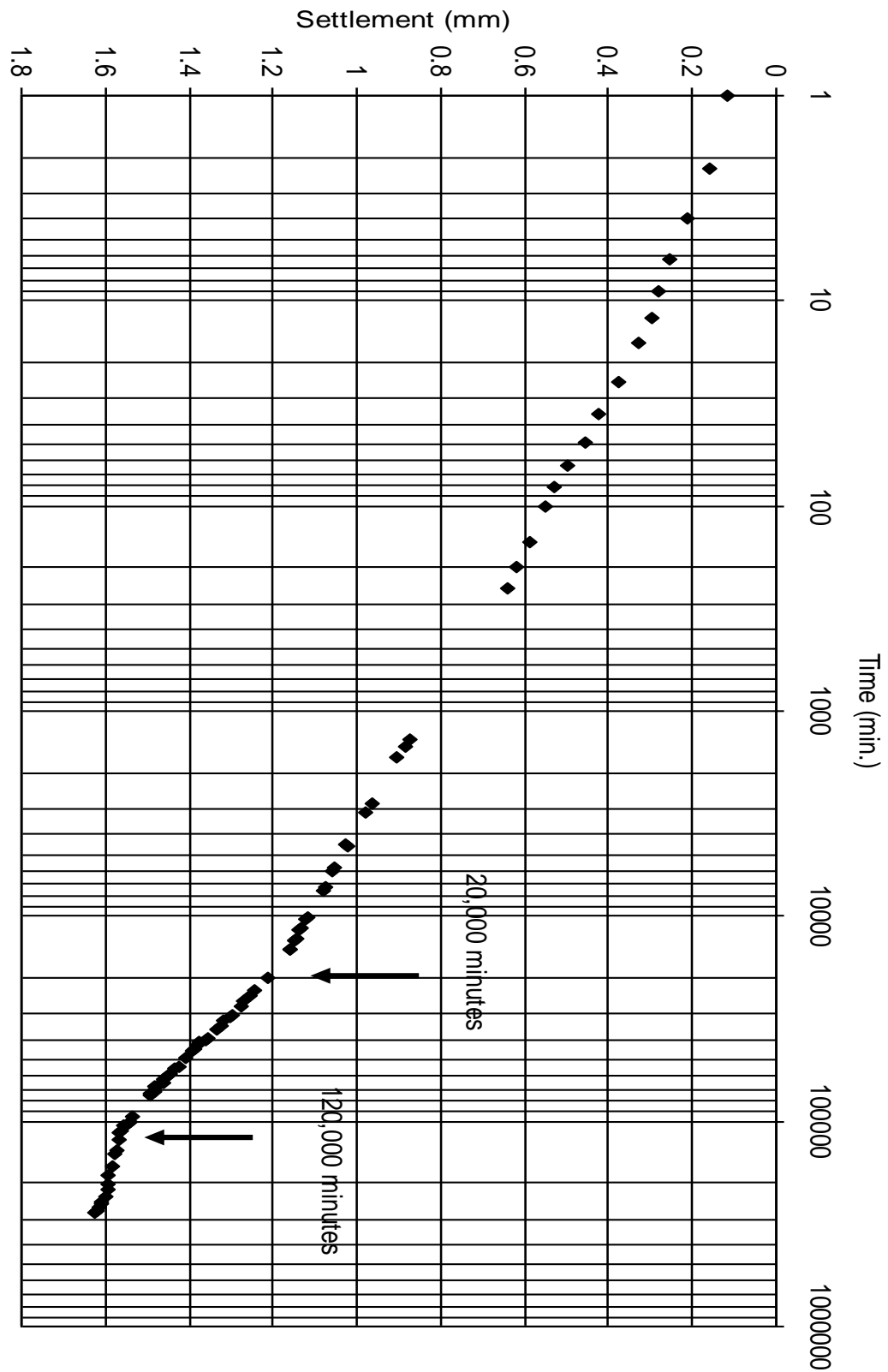
Fig. 7 Long-term Settlement Curve from Undisturbed Sample Taken from Kopundole Drilling Site at 10.5 m Depth. (Time in Log Scale)
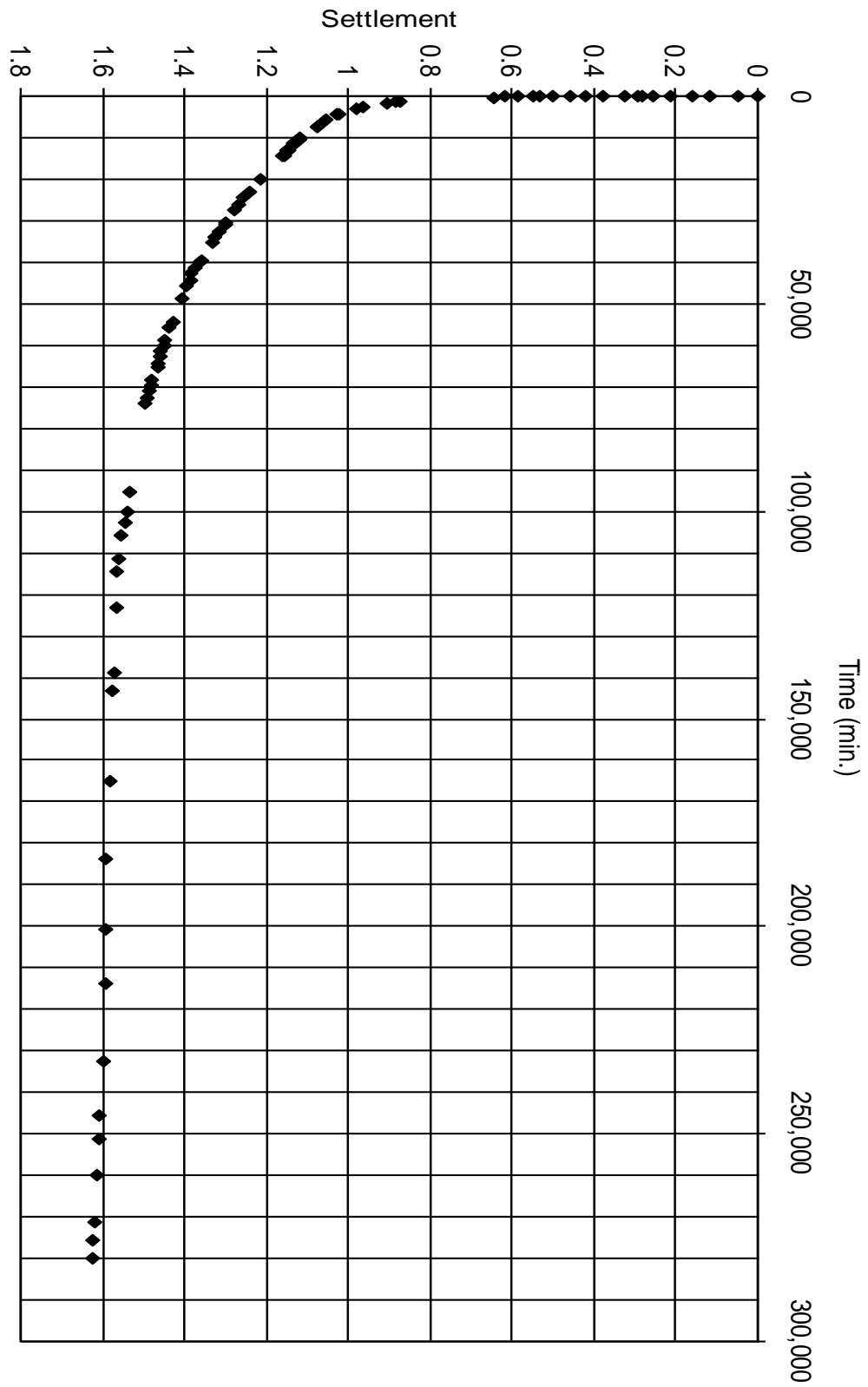
Fig. 8 Long-term Settlement Curve from Undisturbed Sample Taken from Kopundole Drilling Site at 10.5 m Depth. (Time in Linear Scale)

In Fig. 8 the same data as in Fig. 7 is presented with time plotted in linear scale. It can be seen that the curve showed conventional shape similar to that seen in most soils, i.e., an initial steep linear curve and a final very mild more or less linear curve. The difference in the shape of this curve was the very long transition between the first linear part and the final part. The first linear part occurred between 0 to 1478 minutes (causing a settlement of 0.886 mm) could be considered to be the primary consolidation curve. The final part, starting from minute 100,000, could be seen as the curve representing secondary consolidation. It seemed that the method to determine the coefficient of consolidation introduced by Taylor would be more suitable than Casagrade's method.

The long curvature joining these two portions of the graphs depicts the transition between the two modes of consolidation. It can be observed that the transitional part of the curve carried a much large share of the total settlement and spanned a significantly longer period of time compared to those observed in inorganic soils, and could therefore not be ignored as is often the case in treating consolidation data from inorganic soils. The challenging task for Kalo Mato would therefore be to find the right method so that the consolidation and settlement parameters of the soil could be determine with reasonable accuracy.

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