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A Comparison of Engineering Properties of Soils in Two *Kolepadavus* of the *Kole* Lands of Kerala

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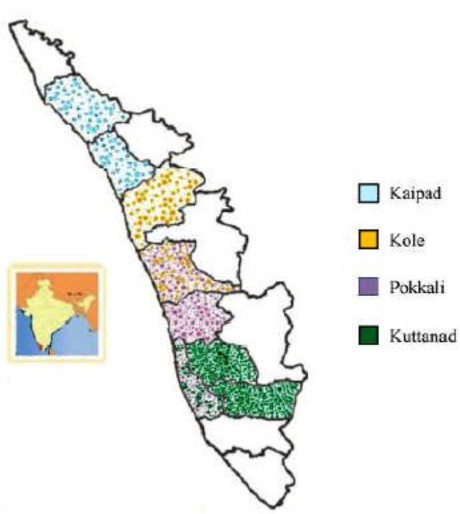
Abstract:
The kole lands lying in the Thrissur and Malappuram districts of Kerala are vast contiguous fertile lands lying below MSL. They remain submerged for about six months every year. After the monsoons these lands are dewatered and rice is cultivated. The yield from these lands is almost double the yield from other paddy growing areas of the State and hence these areas are major contributors to rice production in Kerala. The engineering properties soil of these areas is found to vary widely. The study attempted to classify the engineering properties of soils such as the moisture content, bulk density, soil texture, organic matter, liquid limit, plastic limit, shrinkage limit, penetration resistance and shear strength in two kolepadavus of the kole lands of Kerala.

Key words: Kole lands, bulk density, consistency limit, soil texture, cone index, shear strength

INTRODUCTION

Paddy wetlands are “the lands transitional betweenterrestrial and aquatic systems where the water table is usually at or near thesurface, or the land is covered by shallow water” (Cowardin*et al.*, 1979). As cited in the Article 2.1 of the Ramsar Convention, 1971, “wetlands may incorporate riparian and coastal zones adjacent to the wetlands, and islandsor bodies of marine water deeper than six metres at low tide lying within thewetlands”.

Kerala is home to several special areas put under rice cultivation; *viz.*, the *kuttanad*, *kole*, *kaipad*, *pokkali* etc., each of which have unique and intrinsic characteristics, with the common factor being that all of them are located below mean sea level (MSL). Figure 1 shows the extent of such special, waterlogged areas which were traditionally under paddy cultivation.



(Source: Jayan and Sathyanathan, 2010)

The *kole* lands in Thrissur and Malappuram district of the state come under such a special zone. The *kole* lands were shallow lagoons a very long time back and these gradually got silted up. These lands lie 0.5 m to 1.0 m below the MSL and remain submerged under water for around six months every year, from May-June to October - November. The Karuvannurriver and the Kechery rivers bring their flood waters into the *kole* lands, and then move on to empty into the Arabian sea. Along with the flood water come the rich alluvium, which are deposited in the area, resulting in a very fertile and highly specific soil. The term “*kole*” in Malayalam means a bumper yield of the rice crop that is cultivated here, once in a year. Hence the name of the area indicates the richness and fertility of the land which gives the farmers a bumper yield of paddy.

The *kole* lands lie between the Chalakkudy river in the Thrissur district upto the southern banks of the Bharathapuzha river in the north and between 10° 20’ and 10°40’ N latitudes and 75° 58’ and 76°11’E longitudes (Sivaperuman and Jayson, 2000). The entire *kole* lands are distributed in Thrissur and Malappuram districts with 10187 ha of land lying in the Thrissur *kole*. The Mukundapuram and Chavakkadtaluks constitute a major share of the Thrissur *kole*. The *kole* lands lying in the Malappuaram district are termed as the Ponnani *kole* with an area of 3445 ha and are located in the Thalappillytaluk and parts of Chavalkkadtaluk of the Thrissur district and the Ponnani taluk of the Malappuram district. Thus, these cover a vast land area of 13632 ha, which is cultivated with rice. Canals and channels are provide throughout this area for irrigation and drainage. These also divide the *kole* lands into *kolepadavu*s, i.e., blocks of land, often having area of 200 ha or more, to ensure easy water and crop management (Johnkutty and Venugopal, 1993; Leema, 2015). The *kole* lands are notified Ramsar Heritage sites and have a rich biodiversity of flora and fauna and aquatic life.

These vast tracts of land are put under rice cultivation and contribute significantly to the rice production of the state. The lands which are submerged during the monsoon, are dewatered using the traditional *petti* and *para* system of pumping, or the vertical axis turbine pumps of late; and the water is channelized to the main channels. This water is later used for irrigating the fields.

The soil in the *kole* lands is typical due to the deposition of alluvium and also on account of being submerged under water for long period of time. Generally the soils have been reported to be clays, sandy loams, sandy clay loam and clay loam (Jayan and Sathyanathan, 2010). These lands are also rich in organic matter. However it was observed that generalization of the properties of the *kole* soil was not truly justifiable, as there were variations with locations. Hence it was decided to study the basic engineering properties of soil at two locations in the *kole* lands; viz., the Pullazhi *kolepadavu* in the Thrissur *kole* and the Kolothumpadam*kolepadavu* in the Ponnani *kole*, for similarities or differences, if any.

The engineering properties of soils such as the moisture content, bulk density, liquid limit, plastic limit, shrinkage limit, soil texture, penetration resistance and shear strength and organic carbon were assessed in both the locations. Standard test procedures were followed to collect samples and to analyse these. Table 1 shows the methodologies adopted for determining the soil properties.

Table 1. Methodology adopted for determination of soil properties

Sl. No.	Soil Property	Method Adopted	Reference
1.	Moisture content	Hot air oven method	IS:2720 (Part 2) – 1973
2.	Bulk density	Core cutter method	IS:2720 (Part 29) -1975
3.	Liquid limit	Casagrande method	IS: 2720 (Part 5) – 1985
4.	Plastic limit	Rolling thread method	IS: 2720 (Part 5) – 1985
5.	Shrinkage limit	Standard procedure	IS : 2720(Part 6)-1972
6.	Soil texture	Pipette method	IS: 2720 (Part 4) – 1985
7.	Cone Index	Cone penetrometer	IRRI (1985), ASABE (2011a,b)
8.	Shear strength	Vane shear method	ASTM D2573
9.	Organic carbon	Chromic acid wet oxidation method	Walkley&Black,1934

Soil samples were collected from three different locations at each of the two study sites. Three samples each were collected at each of the three locations within the Pullazhi *kolepadavu* and the Kolothumpadam*kolepadavu*. Hence nine samples were taken from each *kolepadavu*. The collected soil samples were brought to the Agricultural Engineering Laboratory of the Department of Agricultural Engineering, College of Horticulture, Vellanikkara, KAU and analysed as per the methods indicated in the table 1 above to determine the moisture content, bulk density, soil texture, soil consistency limits such as liquid limit, plastic limit and shrinkage limit and organic carbon. The tests to determine the dynamic soil properties such as the penetration resistance (cone index) and the shear strength were determined in situ in the fields.

The results of the experiments conducted are presented below.

1. Moisture content and bulk density:

The results of the experiments conducted to determine the moisture content and bulk density of the soil samples collected from three locations are presented in table 2. The average of the three replications at each of the three locations is presented here.

Table 2. Moisture content and bulk densities of the soil at the two test sites

Location	Sample	Moisture content (%)	Wet bulk density(g cm^{-3})	Dry bulk density (g cm^{-3})
Pullazhi*kolepadavu*	PU1	54.412	1.482	0.960
	PU2	52.632	1.546	1.013
	PU3	57.851	1.443	0.914
Ponnani*kolepadavu*	PO1	66.667	1.862	1.117
	PO2	65.385	1.832	1.108
	PO3	65.462	1.845	1.115

The average moisture contents at the Pullazhi *kolepadavu* under Thrissur *kole* (obtained from three replications at the three test sites, viz., PU1, PU2 and PU3) were found to range between 54.412 % to 57.851 %. At the Kolothumpadam*kolepadavu* under the Ponnani *kole*, the moisture content was seen to vary between 65.385% to 66.667%. The wet bulk density values observed at the Kolothumpadam*kolepadavu* were higher when compared to those at Pullazhi *kolepadavu* and ranged from 1.832 g cm^{-3} to 1.862 g cm^{-3}wet bulk density at Kolothumpadam*kolepadavu* to 1.443 g $cm^{-3}$to 1.546 g cm^{-3}wet bulk density at Pullazhi *kolepadavu*. A similar observation was also made in case of the dry bulk density.

2. Soil Texture:

The particle size analysis carried out as per procedure provided the percentages of the sand, silt and clay particles present in the soil samples, collected as explained in earlier section. After the percentages of different types of particles were determined, these were plotted on to the USDA soil textural triangle, in order to determine the soil types. The result of the tests for determination of the soil particle size distribution and soil type is presented in table 3.

Table 3 Soil particle size and texture

Location	Sample	Sand (%)	Silt (%)	Clay (%)	Total (%)	Soil texture
Pullazhi*kole padavu*	PU1	5.74	48.03	46.23	100	Silty clay
	PU2	6.77	45.53	47.70	100	Silty clay
	PU3	6.72	45.52	47.76	100	Silty clay
Ponnani*kole padavu*	PO1	2.77	41.68	55.55	100	Silty clay
	PO2	4.05	42.22	53.73	100	Silty clay
	PO3	3.34	44.88	51.78	100	Silty clay

Both the Pullazhi *kolepadavu* and the Kolothumpadam*kolepadavu* fell under the category of silty clays. However, there was a considerable reduction in the sand content and increase in clay content in case of the Ponnani *kole* soils when compared to the Pullazhi silty clays. Hence, even though the soil is from the major group of *kole* lands, and also fall under the same textural category, they have different constituent particles, and hence exhibit different behaviour when subjected to dynamic stresses.

3. Soil consistency limits:

The soil consistency limits or the Atterberg limits are basically the moisture contents at which the soil properties change significantly. The liquid limit is the moisture content at which the soil just begins to flow, from the plastic state to the liquid state. The plastic limit is the lowest water content at which the soil transforms from plastic to rigid condition. The water content at which any further moisture reduction does not result in decrease in volume is called shrinkage limit. These limits are indicative of the behaviour of soil when their moisture content changes and are very important. These often come into play when the soil is subjected to the different soil manipulation operations during crop cultivation.

The various soil consistencies determined vide the standard procedures are presented in the table 4. The plasticity index is the difference of the liquid limit and the plastic limit.

Table 4 Soil consistency limits

Location	Sample	Atterberg limits			Plasticity Index
		Liquid limit (%)	Plastic limit (%)	Shrinkage limit (%)	
Pullazhi	PU1	60.79	43.02	15.37	17.77
	PU2	60.60	49.58	11.31	11.02
	PU3	61.38	41.19	9.88	20.19
Ponnani	PO1	69.52	45.00	8.56	24.52
	PO2	67.08	41.78	11.88	25.30
	PO3	69.21	46.48	9.38	22.73

The plasticity index indicates the range of moisture content in which the soil remains plastic and mouldable. With its higher clay content the soils at the Kolothumpadam*kolepadavu* of the Ponnani *kole* had a greater workability.

4. Organic carbon:

Carbon is the majorconstituent of soil organic matter. About 48-58% of the total weight of soil is comprised of carbon. So soil organic matter is estimated by determining the organic carbon and multiplying it by the Van Bemmelen factor of 1.724. Organic carbon of the soil was determined by the chromic acid wet oxidation method (Walkley and Black, 1934). The values obtained are shown in table 5. Both the *kolepadavu*s had a high percentage of organic matter.

Table 5 Soil organic matter

Sl. No.	Sample	Organic carbon quantity (%)	Organic matter (%)	Remarks
1	PU1	3.68	6.344	High
2	PU2	3.15	5.401	High
3	PU3	3.50	6.034	High
4	PO1	3.46	5.965	High
5	PO2	3.54	6.103	High
6	PO3	3.65	6.293	High

5. Penetration resistance (Cone index)

The resistance offered by the soil to the penetrating probe is termed as soil penetration resistance. This is measured using the cone penetrometer. As the cone penetrometer probe is inserted into the soil, the resistance offered to the probe by the soil is measured at incremental depths.

The cone index is calculated as

$$q_c = \frac{(F+W)}{A}$$

where
q_c = cone index, kg/cm^2
F = applied force, (kg_f)
W = weight of the cone penetrometer, (kg_f)
A = base area of the cone, cm^2

The readings were taken in the field at three locations at each site and the average values of cone index are presented in table 6. The measurements were made downwards from the soil surface.

Table 6 Variation in cone index with depth at the two test sites

Depth (cm)	Cone index (kg cm^{-2})	
	Pullazhi*kolepadavu*	Kolothumpadam*kolepadavu*
7.50	1.45	0.20
10.00	1.78	0.28
12.50	2.01	0.31
15.00	3.16	0.41
17.50	4.00	0.55
20.00	5.07	1.00
22.50	5.07	1.02
25.00	5.61	1.86
27.50	5.50	4.20
30.00	5.90	6.46

The cone index (penetration resistance) values are found to be higher in the top layers in the soils of Pullazhi *kolepadavu*. At greater depths of 27.50 cm and 30.0 cm the values were relatively similar. The lower cone index values for the Kolothumpadam*kolepadavu* of Ponnani *kole* may be due to the increased clay content and moisture content. The moisture forms a film around the fine clay particles and thus offers lesser resistance to penetration of the probe of the penetrometer.

Figure 2 shows the changes in cone index at different depths of measurement at the two test sites.

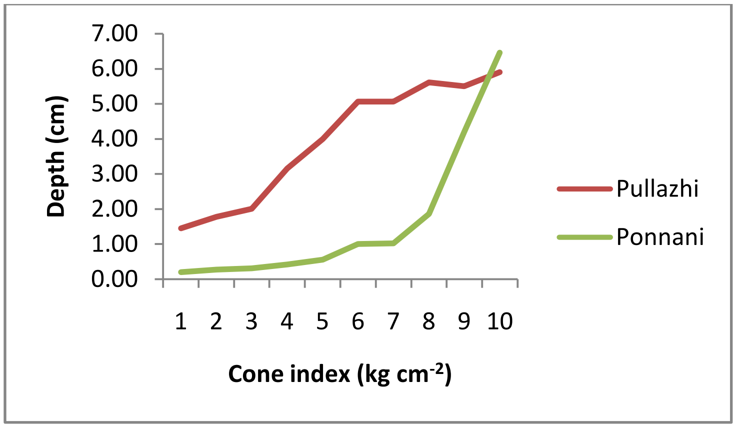


Fig. 2 Variation in cone index with depth

It is observed that the cone index or penetration resistance increases with depth, generally. However, in the Ponnani *kole* soils the increase in cone index is observed to be less at the initial depths and then sharply increases with the depth, indicating that the lower layers of the soil profile have more strength. The increase in the initial layers is comparatively more for the Pullazhi soils and at increased depths they tend to show lesser increase.

6. Shear strength

The shear strength of the test sites was measured in situ using the vane shear apparatus. Readings were taken at depths of 20 cm, 40 cm, and 60 cm to evaluate the variation in strength over the range of depths that are normally affected during cultivation. The values obtained are shown in table 7.

Table 7 Shear strength at different depths at the test sites

Location	Depth (cm)	Undisturbed clay		Remoulded clay		Sensitivity (S_u/ S_t)
		Force (kg_f)	Shear strength (S_u) (kPa)	Force (kg_f)	Shear strength (S_t) (kPa)	
PU1	20	2.00	10.42	0.50	2.60	4.00
PU2		2.00	10.42	0.50	2.60	4.00
PU3		1.50	7.81	1.00	5.21	1.50
PU1	40	8.50	44.28	1.00	5.21	8.50
PU2		9.00	46.89	1.00	5.21	9.00
PU3		8.50	44.28	1.00	5.21	8.50
PU1	60	2.00	10.42	1.00	5.21	2.00
PU2		2.00	10.42	0.50	2.60	4.00
PU3		1.50	7.81	1.00	5.21	1.50
PO1	20	3.00	15.63	1.50	7.81	2.00
PO2		3.00	15.63	1.00	5.21	3.00
PO3		3.50	18.23	1.00	5.21	3.50
PO1	40	14.00	72.94	0.50	2.60	28.00
PO2		14.00	72.94	0.50	2.60	28.00
PO3		15.00	78.15	1.00	5.21	15.00
PO1	60	16.00	83.36	0.50	2.60	32.00
PO2		17.00	88.57	1.00	5.21	17.00
PO3		18.00	93.78	1.00	5.21	18.00

The variation in the shear strength at the test locations, over depth, is presented in figure 3.

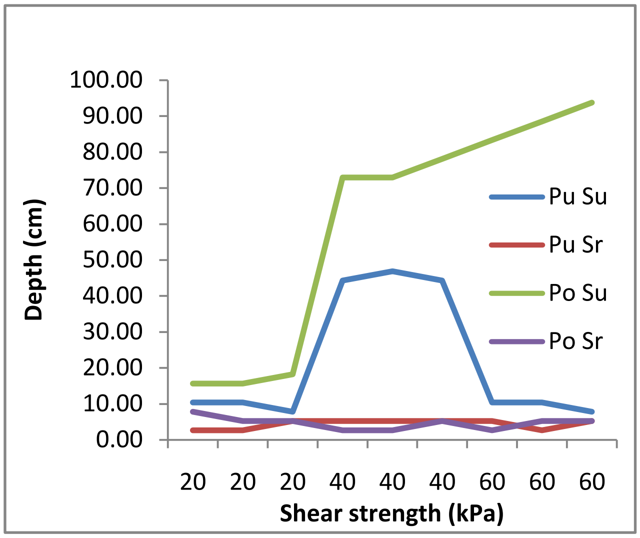


Fig. 3. Variation in undisturbed shear strength (Su) and remoulded shear strength (Sr) over depth at the test sites

The soils at Pullazhi show an increase in shear strength till a depth of 40 cm and afterwards their strength decreases. At Ponnani however isis seen that the shear strength of the soil increase along the depth. The soils below 40 cm depth, at Pullazhi are soft and not consolidated, and have less load bearing capacity. Thus heavy machinery cannot be operated in these fields. Power tillers are the major power sources at Pullazhi *kole* while in Ponnani *kole*, tractors are commonly used for tillage operations.

Conclusion:

The study analysed the various engineering properties of soils at two test sites in the *kole* lands of Kerala. Though the test sites belong to the general category of *kole* lands, and their texture is of the same category, i.e., silty clay, it is seen that their properties vary considerably. These variations permit adoption of different types of machinery in these areas. Different machines are used for land preparation in these areas. As the soil moisture content reduces by the time the crop is ready to be harvested, combine harvesters can be used. Moisture content is however a limiting factor for the use of machinery.

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