1980/18. The stability of a building allotment at Kayena, West Tamar.

D.J. Sloane

Abstract

An area of land adjacent to Kayena Road, Kayena is underlain by up to 0.6m of silty (ML) dark brown topsoil, which overlies at least 2.4m of high plasticity yellowish brown clay (CH). The clay has natural moisture contents above the plastic limit and has high values for Atterberg Limits. Linear shrinkage is high and two tests indicated residual values of the angle of internal friction as 22° and 24° with a corresponding cohesion value of 13.6 kPa in each case.

Stability analysis indicates that the area has short-term stability but is marginally unstable in the long term, assuming zero cohesion and fully saturated conditions. The likelihood of these conditions occurring is discussed and conclusions are reached that the area is stable in the long term.

Recommendations are made as to the siting of french drain dispersal systems for stormwater, septic tank and sullage effluent. It is also recommended that trees be planted on the steeper slopes and care in foundation design and drainage will be required in view of the clay properties measured.

INTRODUCTION

At the request of G.Lauder of Kings Meadows, an investigation was conducted to determine the stability of a building allotment adjacent to Kayena Road, Kayena [DQ920387]. Several visual site inspections over the past two years indicated that the allotment was marginally suitable for building development. Original inspections indicated that both building and the disposal of stormwater and waste water effluent would be suitable in an area located within 20m of the Kayena Road boundary. This area was considered by the Regional Health Inspector to be of insufficient size.

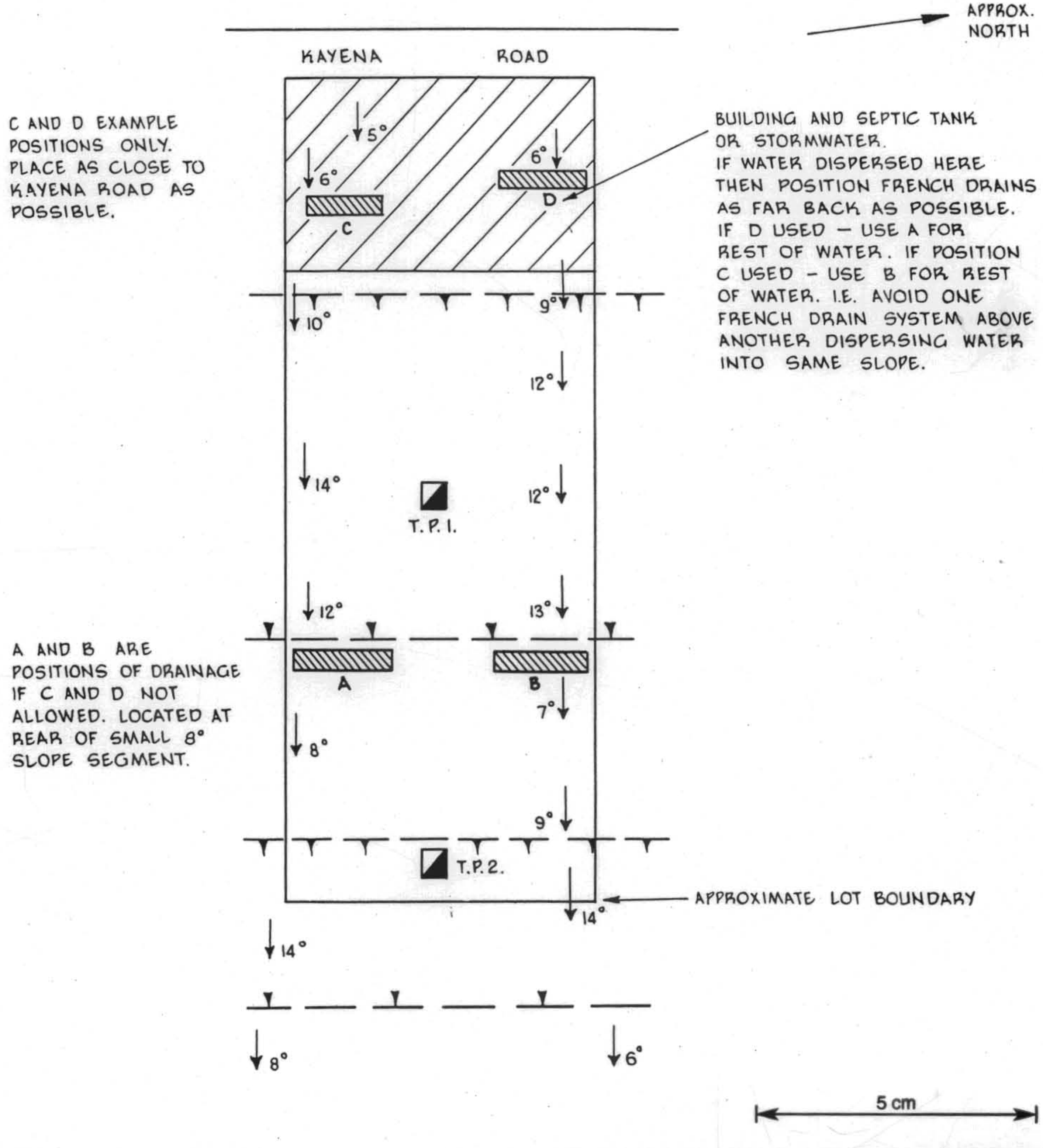
A geotechnical investigation was required to confirm the stability of the allotment. Two test pits were dug by backhoe in the areas indicated on Figure 1. These test pits were logged in detail and selected samples were taken for the determination of natural moisture content, Atterberg Limits, linear shrinkage and shear box testing. Two samples were taken for clay mineral identification. Vane shear and hand penetrometer tests were performed on each test pit.

TOPOGRAPHY

The area is situated just below the crest of a small hillspur adjacent to Devils Elbow on the River Tamar. The hillslope has an easterly aspect and has an altitude of between 15m and 30m above sea level. The hillspur is flat topped and a small bench is located some 10m from the hilltop in the area under investigation. This bench has been considered by other workers to be an old landslip feature, but it is more likely to be structural in origin, located at the base of the harder rocks which cap the hillspur.

LOCATION KAYENA ROAD	SUBURB KAYENA	GEOLOGIST D. J. SLOANE
OWNER G. LAUDER	TOWN WEST TAMAR	DATE 1/4/80

TAMAR VALLEY LANDSLIP ZONE MAP
CLASSIFICATION : ZONE IV AND ZONE I



SCALE APPROX. 1:500 APPROXIMATELY TO SCALE

LEGEND

↗20°	Slope angle and direction	▨	Area in which building advised
	Change of slope - downslope side indicated	▧	" " " septic tank "
	Change of slope - upslope side indicated	T.P.1.	APPROX. TEST PIT LOCATION

Figure 1.

GEOLOGY

The geological map of the area (Gee and Legge, 1971) indicates that the small hillspur is capped by Tertiary basanitic dolerite overlying Tertiary sediments consisting of clay, sand, and gravel. It is these latter sediments which are generally prone to landslip movements.

TEST PITS

Detailed logs of the two backhoed test pits are presented in Appendix 1. In summary the lower section of the building allotment is underlain by 0.6m of silt (ML) topsoil, dark brown in colour and containing some ironstone boulders, and quartz gravel. Below this, to a depth of at least three metres, is high plasticity clay (CH) varying in colour from yellowish brown to greyish yellow and olive-brown, and containing ironstone layers and nodules with some traces of fossil leaf and stem fragments. As with recently inspected test pits at Launceston (Sloane, 1980) dessication fissures extend through the topsoil to a depth of about one metre from the ground surface, imparting a columnar pedal structure. These fissures will allow water to penetrate more readily into the subsurface material, and indicate the mechanism by which water may cause saturation and subsequent instability when heavy rainfall occurs after a prolonged dry period.

X-ray diffraction analysis of two samples of clay indicate that they are composed of quartz and the clay minerals kaolinite and gibbsite.

CLAY ANALYSIS - GEOMECHANICAL PROPERTIES

Four samples have been tested for various properties.

Field moisture content

Field moisture contents were high and consistent and were as follows:-

TP 1	(2m)	-	34.5%,	(3m)	-	37.6%
TP 2	(2m)	-	38.7%,	(3m)	-	34.8%

These figures are expressed as a percentage of dry weight and are all above the plastic limit for each sample.

Liquid limit

Liquid limits of three samples tested were in close accordance. The values are high and ranged between 96.5% for TP 1 to 104.3% for TP 2 both at a depth of two metres.

Plasticity index

This value indicates the moisture content range over which the clay remains plastic. Values ranged from 70.5% in TP 1 to 76.8% in TP 2, both at a depth of two metres. The values indicate high toughness and dry strength and high plasticity and compressibility.

Linear shrinkage

All linear shrinkages measured corresponded closely, ranging betwen 20% and 22%. These values are high.

In situ vane shear testing

In situ vane shear tests provide an indication of the shearing resistance and sensitivity of the clay. Peak values were all off-scale *i.e.* greater than 120 kPa. Residual values were in the range 15 kPa to 48 kPa, generally increasing with depth in each hole.

Hand penetrometer tests

Hand penetrometer tests were generally off-scale *i.e.* greater than 500 kPa. Test pit TP 2 showed a lower value of 450 kPa at a depth of two metres. These readings indicate that for the prevailing moisture conditions, unconfined compressive strengths are generally greater than about 250 kPa or higher and reflect the high dry strength of the clay.

Drained, slow shear box testing

Angles of internal friction $\phi'r$ were determined on samples from a depth of two metres in test pits TP 1 and TP 2. Values closely corresponded with 24° in TP 1 and 22° in TP 2. Corresponding values of cohesion ($C'r$) were identical at 13.6 kPa. These values are residual values determined on remoulded clay samples, and their inclusion in the stability analysis assumes that the clay in the natural slope has previously failed and has residual strength properties.

STABILITY ANALYSIS

For the purposes of this stability analysis, the lowest laboratory measured value of the angle of internal friction ($\phi'r$) will be used. The maximum slope angle of 14° measured by Brunton compass will also be used in the calculations. The area has been considered a simple embankment failure problem with a height of five metres and a slope of 14°. The following clay and slope properties have been considered.

cohesion ($C'r$)	=	13.6 kPa
embankment height (H)	=	5m
angle of internal friction ($\phi'r$)	=	22°
Slope angle (α)	=	14°
bulk density (γ)	=	17.6 kPa (assumed)

Slab failure (Skempton and Delory, 1957)

Assuming the above clay properties and that the embankment is in a fully saturated condition, calculations indicate a range of safety factors from 2.4 for a slab of two metres thickness to 1.8 for a slab of three metres thickness. From the geometry of the slope, a slab failure plane at these depths is most likely and so in the short term the embankment is considered stable. However for long term stability, cohesion should be considered as zero and consequently the factor of safety reduces to 0.71 saturated and 1.6 dry for a slab of any thickness. In fact the saturation factor *M*, which is the ratio of the slab thickness to saturation thickness (M = 1 for fully saturated conditions) needs to be only 0.9 to produce a safety factor of 1.0 even assuming no cohesion. It is considered unlikely that fully saturated conditions will ever occur due to the free draining nature of 0.6 m thickness of topsoil and the fissures which will act both to introduce water to clay at depth, but will also drain the slope through their interconnection. It appears unreasonable to assume that the cohesion value is zero and only a small percentage of the cohesion is needed to increase the safety factor to greater than 1.0. It therefore appears reasonable to assume that the slope is stable, even in the long term and assuming the worst possible condition. Any measures used to increase the stability of the slope will be a further safeguard against failure. These measures will be discussed in the conclusions.

Cousins (1978) stability charts

Assuming fully saturated conditions and the clay properties listed above, the stability charts indicate that the safety factor is 2.2 for critical slip circle failure for toe circles or otherwise with a depth factor of 1.5. Here again only a very small percentage of the laboratory measured cohesion is required to produce a factor of safety greater than 1.0. The embankment appears stable when considering slip circle failure.

Stimpson's (1979) equations

Out of interest, the slope and clay properties were combined to calculate the safety factor for wedge failure. This failure would occur along a plane passing through the toe of the slope, and is slightly different from the slip circle or slab failure. Assuming saturated conditions and no tension cracks, a safety factor of 2.2 has been calculated. The assumption of a one metre tension crack makes a minimal difference to the safety factor. Therefore the slope is considered stable for planar wedge failure.

CONCLUSIONS

Stability analysis indicates that the slope is stable for slip circle failure. Slab failure is most likely to occur at a depth of between two and three metres. The short term stability is unquestionable, but for the long term assuming no cohesion and full saturated conditions, stability is questionable. Fully saturated conditions are unlikely to occur, especially when considering the slope geology and the presence of dessication fissures. It may be unreasonable to assume that cohesion is zero, as only a small percentage of the laboratory determined value will raise the safety factor above 1.0. The presence of ironstone bands will also raise the stability factor as assumptions have been made for the purposes of analysis that the slope is composed entirely of clay with the properties as measured in the laboratory. While additional drainage is not considered absolutely necessary, french drains will increase the safety factor by lowering the water table. If seepages do occur or there is evidence of saturated ground during heavy rainfall periods, it would be advisable to construct french drains to a depth of one metre in order to drain such areas. Since the area to be subdivided is devoid of trees, it is advised that suitable trees be planted on the steeper parts of the allotment. Trees not only lower water table conditions but also have a root binding effect on the soil and clay.

It is recommended that building be restricted to the area within 25m of the Kayena Road boundary. It is also recommended, depending on the opinion of the Health Inspector, that either stormwater or sullage and septic tank effluent be disposed of within this area. The remainder of the waste water should be piped down the slope and discharged in a suitable french drain system at the rear of the small bench, as indicated on Figure 1. This water will then have a distance of 15m to 20m to disperse and is unlikely to saturate the lower 14° slope. If the Department of Health does not allow dispersal on the area adjacent to Kayena Road, it would be permissible to drain both waste water and stormwater down onto the lower bench, provided they are again split up with stormwater draining to the north and sullage and septic tank effluent draining to the south. These areas are indicated on Figure 1. In view of the measured clay properties, especially linear shrinkage values, it is advised that foundations be designed to accommodate these soil movement problems. Flexible pipes should be used for piping waste water down the slope between the upper and lower bench.

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[9 June 1980]

TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG – EXCAVATION

5 cm

excavation no. TP1
sheet 1 of 1

project G. LAUDER — location KAYENA ROAD

co-ordinates DQ920387 — exposure type Backhoe Pit — pit commenced 1.4.1980

equipment — pit completed 1.4.1980

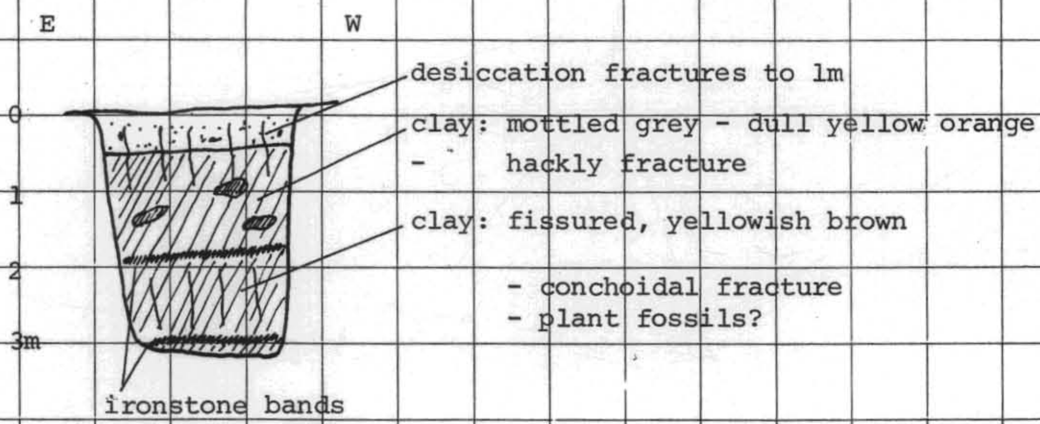
R.L. ≈20m — logged by D.J.Sloane

excavation dimensions 1m x 2.5m x 3m — operator — checked by

penetration 1 2 3	support	water	notes samples, tests	metres R.L. depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour secondary and minor components	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
			Vane shear (kPa)			ML	SILT: Low plasticity. Dark brown. Some well rounded quartz pebbles and ironstone pebbles. Some medium sand.	D	L		A1 soil horizon.Topsoil
			D 19	1		CH	CLAY: High plasticity. Dull yellow orange and grey mottled. Some medium sand and ironstone nodules. Ironstone bands.	M	Vst	>X >X	Desiccation Fissured to 1m depth
			D 15 19	2		CH	CLAY: High plasticity. Olive brown. Some ironstone nodules. Trace of silt. Trace of plant leaf and stem fragments.	M	Vst	>X	Fissured
			D 48	3 END		CH	CLAY: High plasticity. Yellowish brown - bright yellowish brown, grey clay cutans along fissures.		Vst		

r=residual

sketch



TASMANIA DEPARTMENT OF MINES

ENGINEERING LOG – EXCAVATION

5 cm

excavation no. TP2
sheet 1 of 1

project G. LAUDER   location KAYENA ROAD

co-ordinates DQ920387   exposure type Backhoe Pit   pit commenced 1.4.1980
equipment   pit completed 1.4.1980
R.L. ≈15m   logged by D.J.Sloane
excavation dimensions 1m x 2.5m x 2.75m   operator   checked by

penetration 1 2 3	support	water	notes samples, tests	metres R.L.	depth	graphic log	classification symbol	material soil type: plasticity or particle characteristics, colour secondary and minor components	moisture condition	consistency density index	hand penetrometer kPa 25 50 100 200 400	structure, geology
			Vane shear (kPa)				ML	SILT: Low plasticity. Some quartz gravel and medium sand. Dark brown. Some ironstone boulders	D	L		A1 soil horzon. Topsoil Columnar structure
			19r		1		CH	CLAY: High plasticity. Yellowish brown - yellowish olive brown. Trace of silt and fine quartz sand. Some ironstone concretions.			> X	Desiccation cracks. Surface desiccation cracks to 1m. Hackly fracture, some fissures.
			36r		2		CH	CLAY: High plasticity. Dull yellowish brown. Some greyish yellow cutans along fissures. Trace of plant leaf and stem fragments.	D-M / D-M	Vst / Vst		Some fissures
			35r		3							
			r=residual									

sketch