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Published

2014

Conference Title

Proceedings of the International Offshore and Polar Engineering Conference

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Proceedings of the Twenty-fourth (2014) International Ocean and Polar Engineering Conference **www.isope.org**
Busan, Korea, June 15-20, 2014
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ISBN 978-1 880653 91-3 (Set); ISSN 1098-6189 (Set)

Identifying Problematic Soil Layers in Surfers Paradise, Australia

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ABSTRACT

Peat is a highly compressible soil. Surfers Paradise has a peat layer with different thickness at different locations. Buildings in the area are using pile foundations to avoid the peat layer. 35 locations in Surfers Paradise have investigated. Peat locations have been determined within the study area and thickness in each location has been identified. In-situ and laboratory tests results have been obtained for the soil within the study area. The variation of these properties has been plotted and examined. The peat behaviours in Surfers Paradise are assessed and concluding remarks are drawn.

KEY WORDS: Peat; SPT; density; compressibility; water content; shear strength.

INTRODUCTION

Peat covers about 8 per cent of the earth's land surface (Ulusay et al. 2010). The term peat denotes soils with high organic content derived mainly from plant remains. It has a spongy consistency, dark brown to black colour, and strong organic odour in most cases. It can be defined as an unconsolidated organic material consisting mainly of organic residues accumulated as result of incomplete decomposition of dead plant remains under extreme moisture conditions (Landva 2007). Huat (2004) defined the peat as an accumulation of disintegrated plant remnants which have been preserved under condition of high water content and incomplete aeration. Remains of plant fibres occasionally visible but they may not be recognisable in the progressive process of decomposition. Andriesse (1988) stated that the formation of the organic materials is a result of the biochemical process. However, the accumulation process depends on the ecosystem and climate conditions. Irrespective to the geographic location, peat accumulates wherever conditions are suitable, which is, in area with surplus rainfall and poorly drained ground (Huat 2004). According to Radforth (1969) peat can be divided into three main types for engineering purposes. First, amorphous – granular peats which have high colloidal minerals and seem to be like clay in grain structure where the inter-spaces water is kept locked in an adsorbed condition around particles. The two peat types are fine-fibrous and coarse –fibrous peats which hold the inter spaces water in the peat mass as a free water and these types are described as woodier peat. Peat has no precise definition between soil scientists and engineers. Soil scientists have defined peat as a soil with organic content greater than 35% however; geotechnical engineers define the peat as soil with organic content greater than 20% (Huat 2004). From geotechnical engineering's point of view, it is generally accepted that peat is a problematic soil due to its high compressibility, high water content, and low shear strength. The occurrence of organic matter in soils causes a detriment of their geotechnical and engineering qualities (Malkawi et al. 1998). Consequently, a great number of engineers try to avoid construction over peat soils especially if they are without peat experience (Munro and MacCulloch 2006). Peat has an adverse effect on the settlement of foundations and the raft foundations in particular, where the highly compressive peat can bring about exorbitant settlements for buildings erected above it (Oh et al. 2008). Peat shows unique geotechnical properties in comparison with those of inorganic soils such as sandy, silty or clayey soils which are consist of only soil particles (Hashim and Islam 2008). Peat and organic soils normally occurs as unconsolidated, soft and wet deposits as a part of the wetland system. These types of soils may be found as strata underneath other surficial deposits (Huat 2006). He stated that this type of problematic soil can be either avoid the construction on it or remove and replace it. This could be reasonable solution for the surficial peat, but it is possible to perform it on an embedded peat which is found interbedded with other soil strata. This paper identifies the problematic peat layer in Surfers Paradise, Australia as a case study. It also examines the physical and engineering properties of peat in the study area with reference to some peat deposits in some areas.

THE STUDY AREA

Surfers Paradise is considered as a business and tourism hub of Gold Coast, South East of the state of Queensland, Australia. It has been an iconic tourist destination since 1950s and considered as the most famous place throughout Australia. Fig. 1 shows the geographic location of the study area. Surfers Paradise has an area about 4 by 1.3 km^2. The Reduced Level (R.L.) is a calculated elevation of a specific point in relation to a particular datum. As such, the R.L. used in this paper is calculated based on the Australian Height Datum (AHD). The subsoil profile of Surfers Paradise consists of loose to medium dense sand from the ground surface until R.L. 2.3 m. Then a layer of medium dense sand to dense sand between R.L. 2.3 to -3.2 m is encountered. After that a layer of very dense sand is occurred between R.L. -3.2 to -20 m. Within the very dense sand layer, varying thickness peat layer is occurred at depth between (R.L. -10 to R.L. -19.6 m) at different locations with thickness ranging from (0.1 – 7 m). Inter-bedded firm to very stiff clay layers are found up to (R.L. -26.6 m) where a layer of firm to hard clay is occurred below it until the depth (R.L. -29 m). The last layer of this soil profile varies within the study area where in some

locations an inter-bedded layer of medium dense sand, gravelly sand, clayey sand, sandy clay or hard silty clay can be observed.
This subsoil profile is consistent with the description given by Oh et al. (2008), Al-Ani et al. (2013a), Al-Ani et al. (2013b), and Al-Ani et al. (2013c).

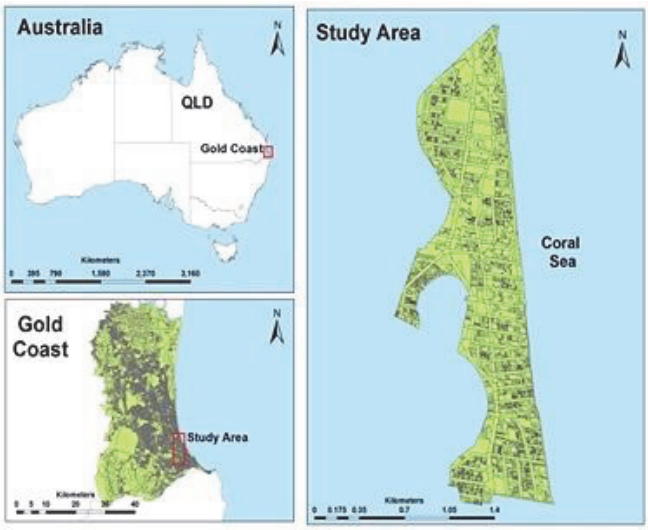

Fig. 1 the location of the study area

Peat formation process started in Australia about 14,700 years ago with accumulation rate averaging about 24 cm each hundred years to produce peat layers which range between 3-6 m thick (Bilney 1997). According to Whitlow (2000), peat deposits occurred due to current and past marine processes near coastal zones. These marine deposits have been laid down ten thousand years ago or during the Holocene geological period. Peat deposits which are found at 26.8m in depth have been aged at 10,585 ± 140 years predating present by using radiocarbon method (Thom and Chappell 1975).

DATA COLLECTION

Data have been collected from 35 locations represent the already erected buildings within the study area. As such, 134 borehole logs from 51 soil investigation reports have been examined. The deepest borehole reached to the depth of 46.45 m below the ground surface and most of the boreholes reached to the depth of bed rocks.

RESULTS AND DISCUSSIONS

Peat Occurrence Locations

The locations of the peat layer occurrence have been determined in Surfers Paradise by using Geographic Information System (GIS). Boreholes data have been processed and showed that 113 boreholes related to 35 locations, contain peat in their stratigraphic profiles (Fig. 2). This peat layer is generally located between R.L. -10.0 m to R.L. -19.6 m. However, it has been observed that the peat layer is located ± 1 - 2 m in some other locations. As such, this peat layer has a thickness of between 0.1 m to 7.0 m within the study area.

Cross Sections

A cross section has been established in the study area where majority of the high rise buildings are erected. This cross section has a direction of North-South and passes through 17 boreholes for a distance of 576 m. The distance between boreholes ranged between 20 to 45 m, but only in two locations the distance was 55 m and 78 m. The vertical and the horizontal scale of this cross section were 1:250 and 1:2,500 respectively. This cross section has identified the extent of the peat layer in north-south direction in the core of the study area. In addition, it showed the horizontal variation in the thickness of peat with depth along the nominated distance (Fig. 3). This cross section also showed that the peat layer is located at depths between R.L. -8.15 to R.L. -21.7 m with a thickness ranging from 0.1 to 6.0 m. However, as stated previously, the peat occurs at depth between R.L. -10.0 to R.L. -19.6 with a thickness ranging from 0.1 to 7.0 m within the whole area of Surfers Paradise.

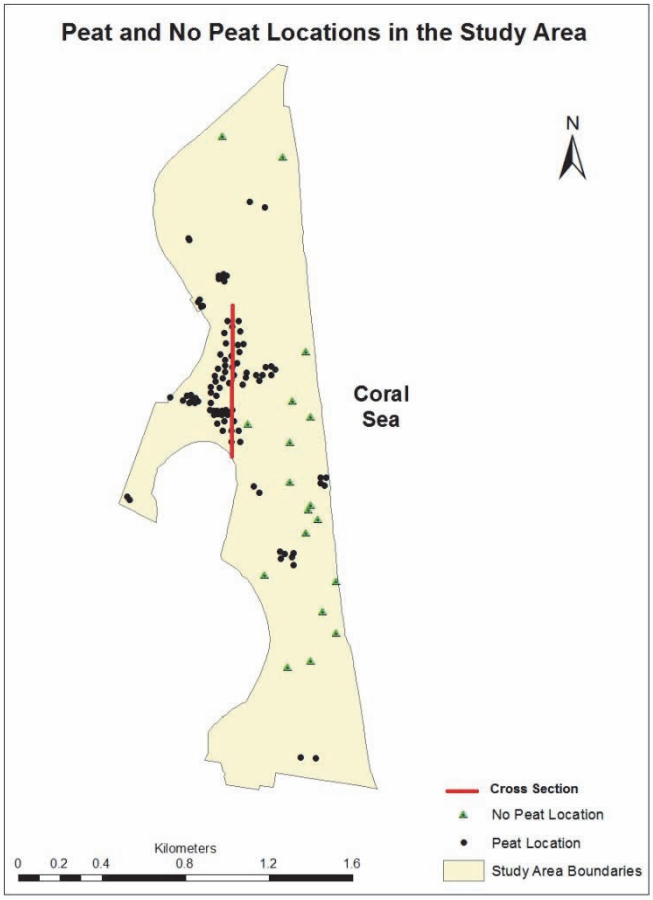

Fig.2 Peat occurrence and cross section locations in the study area

Physical and Engineering Properties of Peat

Standard Penetration Test SPT-N value, energy corrected N_{60}, overburden pressure corrected $(N_1)_{60}$, dry density, water content, estimated void ratio, undrained shear strength, and estimated compression index C_c have been plotted with depth in Surfers Paradise (Fig.4). The purpose of this is to examine the variation of these physical and engineering properties of peat and soil in the study area. It can be observed from Fig.4 that the peat layer is existed at depth between R.L. -10 to R.L. -15 based on specimens taken during the soil investigations at these depths.

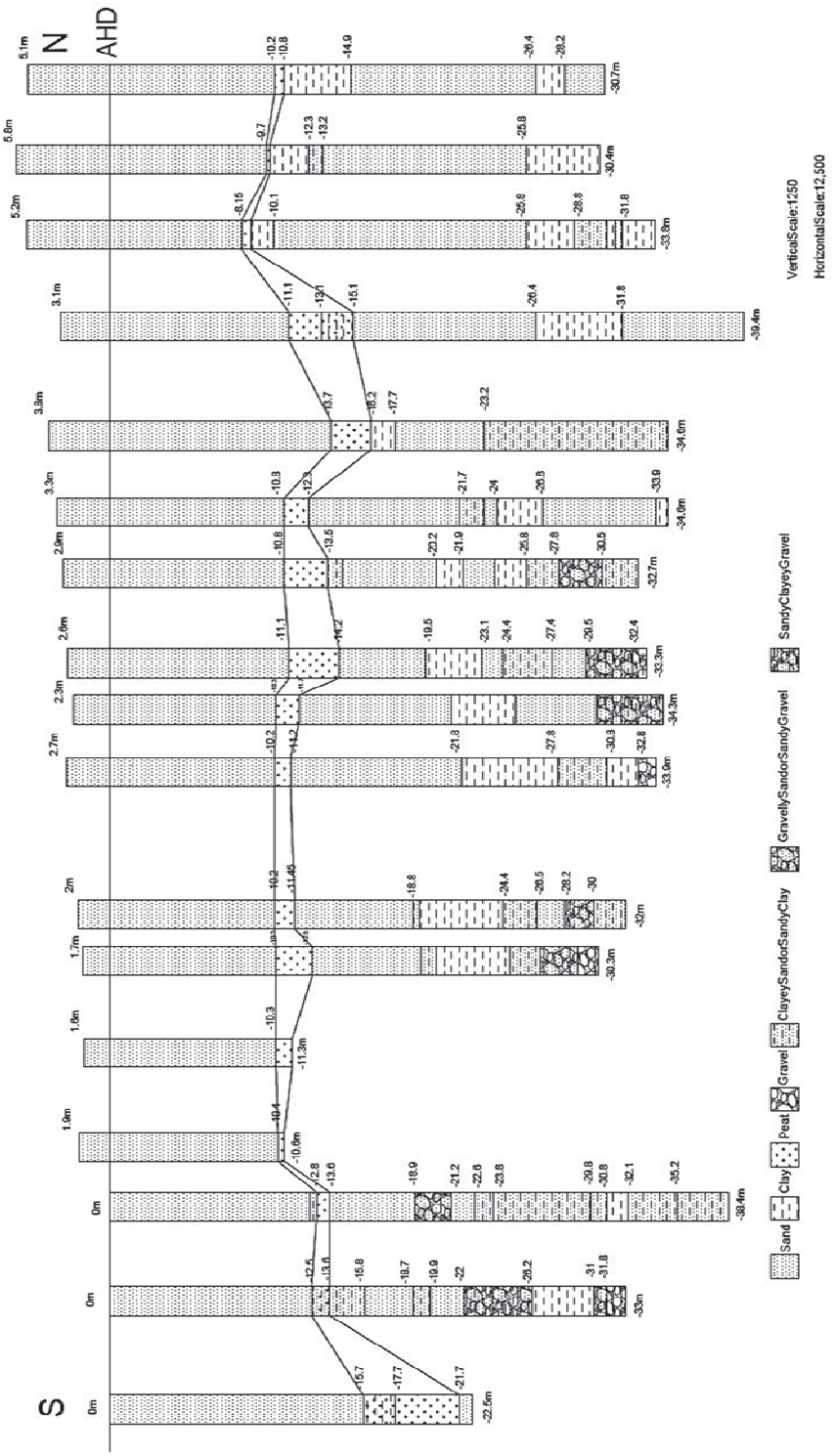

Fig. 3 North-South direction cross section showing the extent of peat layer in Surfers Paradise

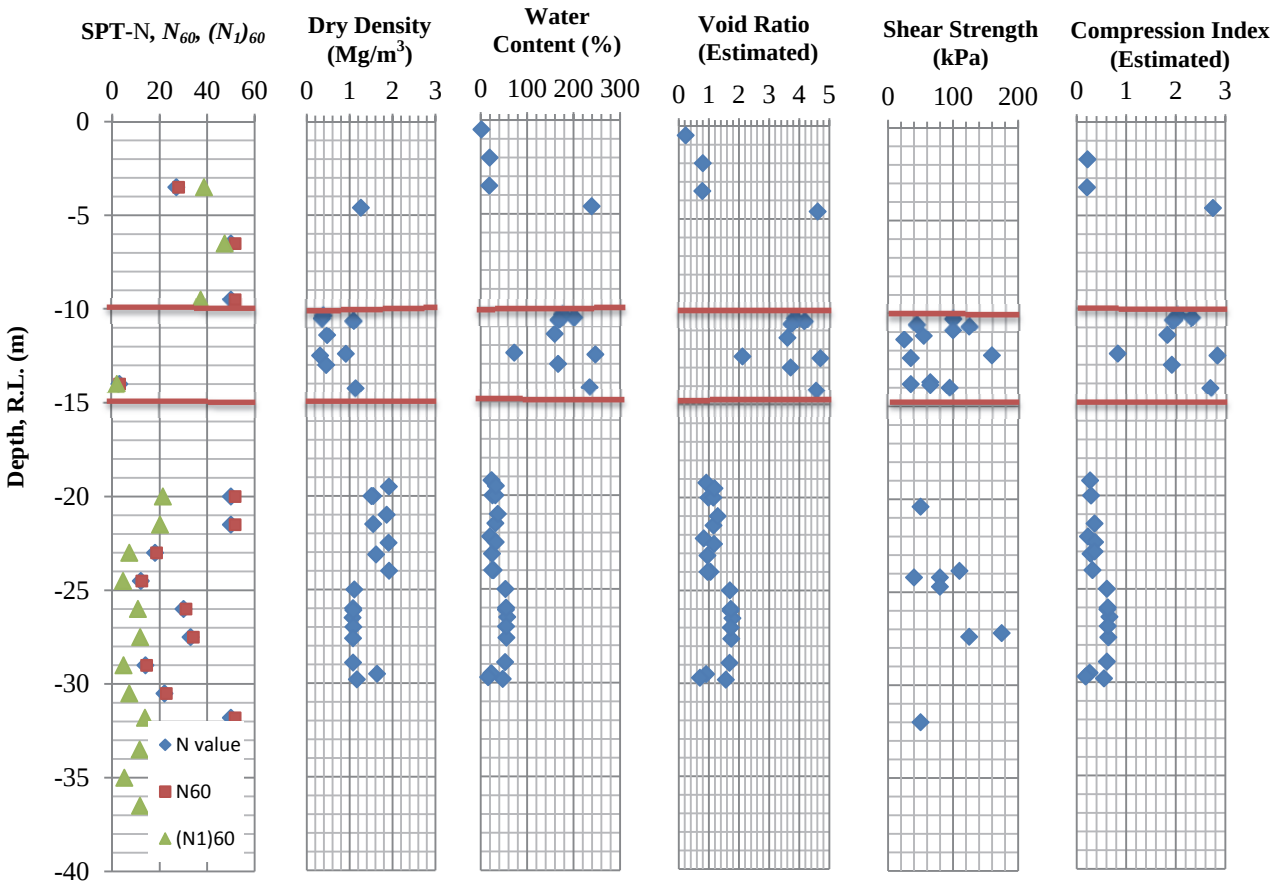

Fig. 4 The variation of some physical and engineering properties of peat and soil in Surfers Paradise

The locations of these data are in the centre of the study area where most of the high rise buildings are erected. Data used in this profile have been obtained from 35 locations based on 51 soil investigation reports. These compiled data are representative to each soil type (sand, clay, and peat) in the centre of the study area. The characteristics of peat are represented by low SPT-N value (3 blows), low dry density (0.31 -1.14 Mg/m^3), high water content (72.2 – 247.1%), high void ratio between (3.6-4.7) (estimated from water content based on an empirical equation proposed by Huat (2006)), undrained shear strength of between (25 – 160 kPa), and the compression index of peat (estimated from water content based on an empirical equation proposed by Azzouz et al. (1976)) was between 0.83 – 2.84.

Normally, peat has low shear strength values and these values vary from location to location based on many factors such as fibres content, type of peat's parent materials, degree of humification, and water content.

It can be noticed that the peat layer in Surfers Paradise has relatively high undrained shear strength values (160 kPa) and this is because the occurrence of significant woods in the dark brown peat. In addition, this value could be attributed to the orientation of the woody fibrous peat. The spatial orientation of these fibres can provide reinforcement and enhance the strength behaviour of peat if the direction of the load is in the same direction as the fibres (Kazemian et al. 2011). It can be observed from Fig. 4 that the SPT values of peat were 8 blows as an average. This reflects the weakness in the peat structure due to high water content in the peat mass. In addition, Peat and organic soils have shown low dry density values compared with mineral soils. These values decrease with the increase of water content based on what it has been reported by Duraisamy et al. (2007) and Den Haan (1997) of more established organic soils of the temperate genesis in Malaysia and the Netherlands respectively. Further, dry density of peat decreases with the increase of liquid limit, so the high liquid limit is the low dry density will be. This is consistent with Kolay et al. (2010) for tropical peat soil in the Matang area in Sarawak, Malaysia. Furthermore, the dry density of a soil decreases with the increase of organic content. This justifies the low dry density values of the peat in the study area which has been associated with the high organic content of 80 % (20 % ash content). This is consistent with Huat et al. (2009) for the tropical peat of Malaysia. Organic content and peat have a negative impact on liquid limit and plasticity index of soil (see Table 1). Holtz and Krizek (1970) stated that there is an increase in the plasticity index with an increase of liquid limit for soils with increasing amount of organic content. Void ratio values in this study have been estimated from water content based on an equation proposed by Huat (2006). The estimated void ratio values of peat in

the study area were within the range of 3.61 to 4.70. Huat et al. (2009) pointed out that the values of void ratio for the peat in Johore, Perak, Sarawak and Selangor of Malaysia were ranging between 1.0 - 7.88. There was no sufficient compression index data of peat and soil in the study area. Hence, compression index values have been estimated from water content based on equation proposed by Azzouz et al. (1976) for peat and organic soils. The measured compression index values of peat were between 0.25 – 1.229 (see Table 1), whereas, the estimated compression values were ranging between 1.83 and 2.74. The reason of obtaining estimated values higher than the measured values could be attributed to the fact that the peat layer in the study area is located at depths between R.L. -10 m to R.L. -19.6 m which means it is already compressed at this level of depth. Normally, the compression index increases with the increase of water content, liquid limit, and void ratio. However, compression index decrease with the increase of dry density as shown in Fig. 4 with depth. The physical and engineering properties of the peat layer in Surfers Paradise have been given in Table 1. Data used in Table 1 are representative to the peat layer embedded in the soil profile of the study area. These data have been obtained from 117 boreholes located within the boundary of the study area where the deepest boreholes reached to the depth of 46.5 m below the ground surface.

Table 1 Properties of peat in Surfers Paradise

Properties	Values	Properties	Values
Liquid Limit	259 – 305 %	Coefficient of Secondary Consolidation	0.029 – 0.044
Plastic Limit	125 – 207 %	Over Consolidation Ratio	1.1 – 2.8 %
Plasticity Index	88 – 134	Apparent Cohesion	43 - 166 kPa
Water Content	168 – 247 %	Apparent Friction Angle	0 – 14˚
Dry Density	0.37 – 1.26 t/m^3	Shear Strength	25 – 160 kPa
Coefficient of Consolidation	1.12 – 11.6 m^2/year	Ash Content	20%
		Specific Gravity	1.572
Coefficient of Volume Compressibility	2.4E-04 – 6.63E-04 m^2/kN	Permeability	9.6E-10 – 2.40E-05 m/sec
Compression Index	0.25 – 1.229	Organic Content	80 %

CONCLUSION

Peat is considered as a problematic soil from the geotechnical engineering point of view due to its high water content, high compressibility, and low shear strength. In this study, North-South cross section has been established in the study area and showed the extent of the problematic layer underneath the engineering structures in the study area. This cross section showed the occurrence of the problematic peat layer at the depth of between R.L. -10 to R.L. -19.6 m with a varying thickness ranging between 0.1 – 7.0 m. In addition, the locations of the peat layer occurrence have also been specified underneath the study area engineering structures. Further, the Standard Penetration test N value and its related parameters N_{60} and $(N_1)_{60}$ have been obtained peat and it was between 0 – 3 blows. Furthermore, the dry density values were between 0.31 -1.14 Mg/m^3, water content values were between 72.2 – 247.1%, estimated void ratio was between 3.6 - 4.7, undrained shear strength values were between 25 – 160 kPa, and the estimated compression index of peat was between 0.83 – 2.84.

These values showed ranges of physical and engineering properties of the peat in Surfers Paradise and were consistent with what have been reported for some peat deposits in the literature.

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