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Construction of Infrastructure on Peat: Case Studies and Lessons Learned

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Abstract. Construction of infrastructures on peat land is a very challenging task due to its properties of low shear strength, high compressibility and high water content. This paper summarizes various solutions which could be adopted for the construction of infrastructure on peat, as reviewed by the experts and panels during IConCEES International Workshop 2015. Engineers could (a) avoid peat, such as to transfer the load to the hard layers through end bearing piles or to replace the peat with the other soils, or (b) construct on peat with special precautions, such as by reducing the weight of the construction materials and dewatering the peat to improve the engineering properties. This paper serves to generate new ideas and give insights of the problems commonly encountered by the industry. Some of the proposed solutions might never be tested on peat. This would rely on the researchers to take up the challenge to further investigate and address the technical issues outlined in this paper.

1 Introduction

Peat is brownish-black in dye which consists of decayed organic and mineral substance (Figure 1). It is a naturally occurring highly organic substance derived primarily from plant material [1]. It is formed when organic matter accumulates more quickly than it decays. This usually happens when the organic matters are preserved below high water table like in swamps or wetland.

In Malaysia, approximately 8% of the total land area (32,975,800 ha) is covered with peat. Sarawak is the state having the largest area of peat, which is approximately 69% of the total peat land area. Although the utilization of peat land is quite low, the demand has been rapidly increasing due to the population growth and various economic reasons. Normally, engineers prefer to avoid having constructions on peat. However, this option might not always be feasible.

Peat is often considered problematic for the construction due to its low shear strength, high compressibility and high water content. These characteristics lead to the problems and difficulties in the construction in various aspects such as pre-construction difficulty, post construction failures, cost of construction, maintenance issues, as well as short and long term impacts. The challenges of constructing infrastructures on peat are to adopt a sustainable design, select suitable materials, reduce the cost of construction, prolong the service duration, and minimize the necessity of maintenance.

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For this, IConCEES International Workshop 2015 was organised on 12-13 October. This workshop invited the 12 keynote and expert speakers from various countries, such as Malaysia, Thailand and Indonesia, and assembles about 47 panels from the sectors of academic, industry, governments and R&D to study the problems and propose solutions for the construction on peat. The expert speakers and the panels are divided into two groups, discussing on two main themes, which are buildings and infrastructures. This paper reports the outcomes obtained from the workshops, focusing mainly on infrastructures.

Figure 1. Large amount of organic substance and water content in peat [2].

Table 1. The area (ha) of peat in Malaysia [3].

State	Area (ha)	Percentage (%)
Sarawak	1,697,847	69.08
Selangor	164,708	6.70
Pahang	164,113	6.68
Johor	143,974	5.86
Sabah	116,965	4.76
Terengganu	84,693	3.45
Perak	69,597	2.83
Kelantan	9,146	0.37
Negeri Sembilan	6,245	0.25
Federal Territory	381	0.02
Total	2,457,669	100

2 Proposed Solutions

The most common problems related to the construction of infrastructures can be categorised as (a) settlement of peat, (b) low bearing capacity of peat, (c) poor stability of peat during excavation and (d) high ground water table. Various solutions were proposed to resolve these problems.

Settlements could occur at various modes, such as tipping, differential and uniform settlements, depending on the conditions of peat. These settlements, in excessive, affect the durability and smooth riding of roads or highways. To eliminate the settlement of roads, pile foundation with suspended slabs can be used.

The arching effects of aggregate could be used to substitute the suspended slabs to control the settlement. Aggregates can be arranged in the form of arches, and being supported by the pile foundation. The loads of the traffic and road embankment are supported by the aggregate arch and to be transferred to the hard layer underneath the ground through the piles. Geosynthetics could be used depending on the thickness of the embankment and the span-height ratio of the aggregate arch. In the case that the embankment thickness is insufficient where the span-height ratio is relatively high, it behaves as a partial arching and the aggregate arch might not be effective. Thus, the geotextile is required between the pile caps and the aggregate arch to provide restraint to the arch (Figure 2).

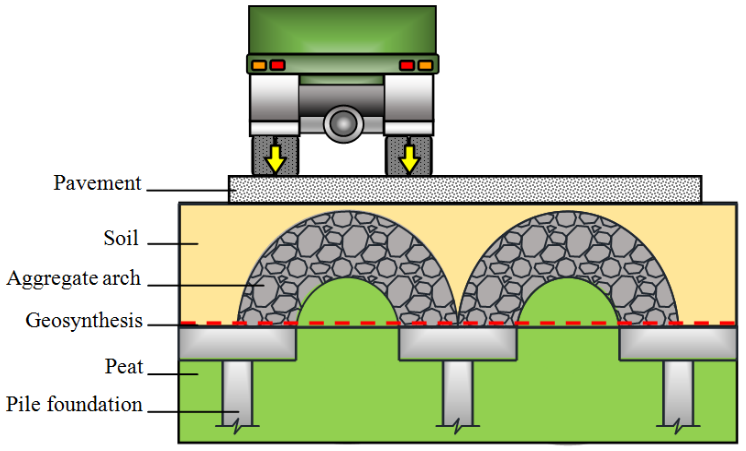

Figure 2. Aggregate arches with pile foundations.

This system, however, inherits certain limitations. It probably requires a huge amount of end bearing piles and thick embankment might be required to ensure a full arching effect. Investigation should be carried out to (a) determine the feasibility, and (b) model the behaviour of the system, to study the effects of the span-height ratio, distance between the piles and the thickness of the embankment. Researchers also need to work out a suitable construction method and the design guide, with and without Geosynthetics, for this system.

The lightweight Geo-materials, such as EPS, foam concrete and tire shreds, could be used as the materials for the construction of roads and highways. In principle, this method minimizes the weight imposed onto the road embankment, and thus, reduces settlement. On the peat with high ground water table, the buoyancy force of the water could be utilized to float these lightweight Geo-materials. For this, it is essential to ensure the weight of road pavement is equal to the weight of excavated peat in order to prevent settlement.

There are several technical issues that need to be resolved while adopting the system. For example, the water level fluctuation, the phenomena of ground water drawdown during the construction, the vertical and lateral restrains of the platform, undesired stresses incurred due to differential settlement of the peat and others. Studies should also be carried out to investigate the strength and the load resisting parameters, to develop a workable system and to acquire the design guide for the system.

For the construction of pipelines, differential settlement at the supports could cause undesired stresses and damages of the pipes. The challenge is to minimize the differential settlement throughout the entire pipeline. Lightweight materials could be used to encase the pipelines to be supported by the low bearing capacity of the peat. For this, the feasibility of the system, the mechanism of supporting the pipelines, the methods of construction or installation, and the connections of the pipeline need to be studied.

Due to the low bearing capacity of peat, it is sometime difficult to access the site during the construction stage (Figure 3). Lightweight materials in the forms of mattresses could be laid and floated on the peat as the temporary platform and access for the construction. For the research, the scopes that could be studied involve (a) determination of suitable materials with the desired engineering and physical properties, (b) the stability of floating mattress platform under various loading conditions, (c) the prolonged life span and the service duration, (d) the mechanism of installation and the performance of joints of the floating platform.

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Figure 3. Severe settlement of the tractor due to poor bearing capacity of peat [4].

Deep excavation on peat with high ground water table could lead to instability of soil or slope. The dramatic drawdown of the ground water table as a result of excavation leads to high mobility of the seepage flow and this causes the failure of the slope. To resolve this, a groundwater barrier is required to cutoff or control the flow in order to ensure the stability of the slope. This could be done through various mechanisms, such as gravity mass, diaphragm wall, sheet piles, jet grouting, stone columns and soil mixing piles. These methods are relatively costly compared with the dewatering scheme.

Dewatering the construction site on peat is known to be able to improve the engineering properties of the peat in order to ensure the stability of the slopes during excavation. However, excessive extraction of the water leads to significant settlement of the ground and, in most of the time, a large region is affected. This could affect the existing structures nearby, which are beyond the construction site. For this, a recharge pond lining system could be used to maintain the ground water table at the regions where excavation works are not required in order to minimize the affected region. Investigation is required to acquire the response of dewatering and its affected region and to model the rate of recharging process. Studies could be extended to determine the setback distance or area and mechanisms to minimize the required setback so that it is applicable for small construction sites.

In addition, the centralized sewerage network system could be strategized to be used as a mechanism of dewatering during the construction stage prior to its actual usage after the construction. Similarly the combination of subsoil and open channel drainage systems could be strategized and used to control the ground water table and to maintain the engineering properties of the peat. In normal days, the subsoil drain can be used to retain water and slowly discharge the water. Under the overflow condition, the open channel can be used to rapidly discharge the water. The feasibility of these methods, in a separate or combined system, needs to be studied.

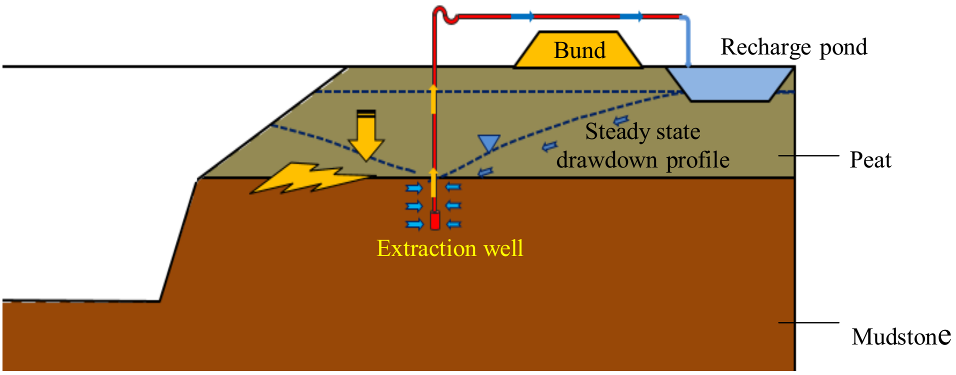

Figure 4. Dewatering scheme using extraction well and recharge pond [2].

Peat could be removed to expose a firm layer of sufficient bearing capacity and replaced with suitable materials with the desired engineering properties, e.g. road embankment. This method is economically viable for the depth of up to 4.0 m.

Earth filling at a deep peat area causes lateral movement of the soil. This causes the undesired lateral load to the pile foundations of the nearby structures, and this could jeopardize the stability and the integrity of the structures. For this, suspended slabs are usually adopted with a minimum amount of earth filling. The void underneath the suspended slab is recommended to be filled and compacted in order to prevent accumulation of the hazardous gases.

3 Discussions

These methods function on the basis of (a) avoiding the use of the peat by transferring load to the hard layers underneath it, (b) reducing the weight of materials to be lighter than water to “float” the structures on the peat, (c) controlling the seepage flow to avoid the instability of the slope during excavations, (d) improving the properties of the peat through dewatering, and (e) replacing the peat with the soils with better engineering properties (Table 2).

Table 2. Classifications of the approaches used by various method.

Methods	Approaches				
	Load Transfer	**Reduce Weight**	**Seepage Flow Control**	**Dewatering**	**Peat Replacement**
Pile foundation • with suspended slab • with aggregate arch	√				
Lightweight Geo-materials • EPS, Foam concrete, tire shreds		√			
Groundwater Barriers • gravity mass • diaphragm wall • sheet piles • jet grouting • stone columns • soil mixing piles			√		
Dewatering schemes • Extraction well and recharging pond • Sewerage system • Subsoil drainage				√	
Excavation and earth filling					√

Out of the methods proposed, not all have successfully been applied on peat at a full scale. Some of these methods are at the conceptual stage, at least for the time being. Some have been tested on soft soils, but not on peat. It is still unsure of the feasibility and practicality of these methods. For this, simulation models are required, experimentally, numerically or analytically, to determine the feasibility and to acquire the response of the peat prior to adoption of the stated systems. These include the aggregate arches, dewatering schemes by using sewerage and drainage network systems.

4 Conclusions

IConCEES workshop provides a platform for the experts and panels from the sectors of academic, industry, government and R&D gather thoughts and propose various solutions to the construction of infrastructure on peat. The aim was to generate new ideas and give insights on the problems encountered by the industry for the researchers to investigate and to resolve. At this stage, we are yet to acquire a perfect solution. Different method inherits its own limitations and there are still many technical issues to be addressed. These are the challenges to be undertaken by the researchers all around the world. By having those limitations and technical issues resolved, we are a step closer to a better solution.

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References

[1] Construction Research Institute of Malaysia, Guidelines for Construction on Peat and Organic Soils in Malaysia, 129, (2015).
[2] L.S. Shong, Problems and solutions of peat soils in engineering applications, presentation slides, *IConCEES international workshop 2015*, Sibu, Sarawak, (2015).
[3] Wetlands International Malaysia, A quick scan of peatlands in Malaysia, Petaling Jaya, Malaysia, 74, (2010).
[4] A.L.L Kong, Jurutera, Institution of Engineers Malaysia, June, No.6, (2005).