Use of Lightweight Cellular Mats to Reduce the Settlement of Structure on Soft Soil

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Abstract. Construction of structures on soft soils gives rise to some difficulties in Malaysia and other country especially in settlement both in short and long term. The focus of this research is to minimize the differential and non-uniform settlement on peat soil with the use of an innovative cellular mat. The behaviour and performance of the lightweight geo-material (in block form) is critically investigated and in particular the use as a fill in embankment on soft ground. Hemic peat soil, sponge and innovative cellular mat will be used as the main material in this study. The monitoring in settlement behavior from this part of research will be done as laboratory testing only. The uneven settlement in this problem was uniquely monitored photographically using spot markers. In the end of the research, it is seen that the innovative cellular mat has reduce the excessive and differential settlement up to 50% compare to flexible and rigid foundations. This had improve the stiffness of soils as well as the porous contain in cellular structure which help in allowing water/moisture to flow through in or out thus resulting in prevent the condition of floating.

Keywords: Ground modification, soft soil, geo-infrastructure.

1. Introduction

The construction and structure played an important role in Malaysia thus allowing many companies and firms of consultancy and contractors have begun to competitively and also cooperatively to design, build and make a building to be unique and ideal for local and foreign consumers. However, some of the constraints faced by every company that involved the construction of structures on soft soils which undergo settlement in the short or long term. Soft soils experience with low strength and rapid settlement for some foundations in unavoidable circumstances which lead to the ground failure. An example of soft soils is soft organic clays which have the characteristics of very low shear strength and lacks compressibility [1,2]. An extreme failure example of soft soil is organic peats [3,4]. Figure 1 shows the area covered by peat soils in Malaysia [5]. These challenges arise towards engineer facing in all sorts of problem to design and construct foundation of building, road and highway embankment. It is because structures construct on peat soil are often affected by stability due to high compressibility, low shear strength and high permeability [6,7]. The most critical geo-environment challenges are excessive settlement and differential settlement leading to hazardous and discomfort in road usage. Many conventional methods (pile, vertical drain, soil replacement, soil stabilization etc.) have been used to reduce these problems. However due to self-weight from the conventional methods used could not maintain the soil structure allowing them become as secondary subject towards excessive in soil settlement.

Figure 1. Location of peat swamps in Malaysia (Zainorabidin et al., 2007)

Settlements can be occurring in three different ways such as:

(i) Uniform settlement – The structure settled constant and uniformly
(ii) Tilt settlement – The structure experience in differential of settlement
(iii) Non-uniform settlement – The structure settled due to elongation

These three types of settlement can be seen according to the related places which sketched in Figure 2 [8]. The purpose of this research study is to investigate the settlement behaviour of peat soil and sponge which combine with and without the application of innovative cellular mat through physical model testing.

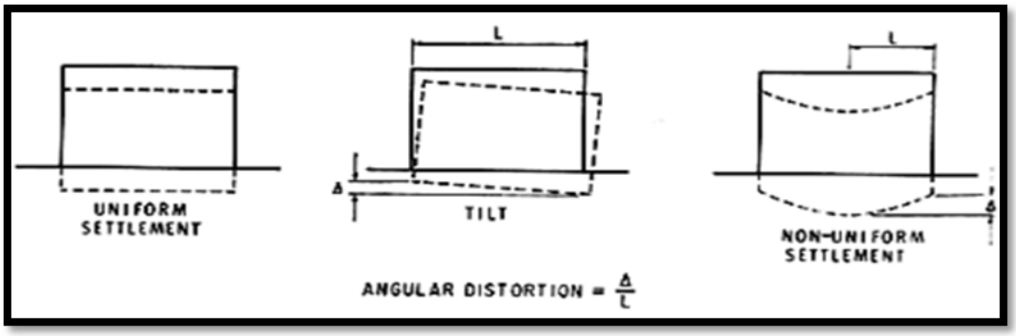

Figure 2. The diagram in types of settlement (WUS Austria, 2007)

2. Materials and methods

The primary step carried out in this research includes in computing the stiffness of sponge and the moisture content of the hemic peat soil where else the parameters of the hemic peat soil was taken through past literature review as shown in Table 1. A geo-composite material will be used as a main product in this study. This material act' as a lightweight fills material to exert little pressure to soft soil and also to reduce the self-weight of embankment. The physical modelling test was carried out in RECESS by monitoring the soil settlement behaviour in the view of 2-Dimensional (2-D). The laboratory model tests will be conducted in a steel tank of size 100cm (length) x 50cm (width) and 60cm (height). This model testing will be used to:

i. Investigate the settlement behaviour on peat soil and sponge only (without innovative cellular mat)
ii. Investigate the settlement behaviour of peat soil and sponge by application of innovative cellular mat.

Table 1. Physical properties of typical hemic peat soil in Johore, Malaysia (Adapted from Zainorabidin et.al, 2007)

Parameters	Value
Bulk Density	7.5 – 10.2 kN/m3
Water Contents	230 – 500 %
Organic contents	80 – 96%
pH	3 – 4.5
Specific Gravity	1.48 – 1.8
Shrinkage Limit	-
Plastic Limit	-
Liquid Limit	220 – 250%
Plasticity Index (%)	-
Undrained Shear Strength (kPa)	7 – 11
Compression Index, Cc	0.9 – 1.5

In this testing two different material used (sponge and the peat soil) was modelled under the three condition of foundations. They were in the form of flexible, rigid and finally in mats. The surface of the both materials was applied directly with increment loads up to 500N. The settlement data will be taken from the clear image of DSLR camera (Figure 3) then transfer them to Microsoft Excel for further analysis.

Figure 3. The constant position of DSLR camera during conducting the experiment.

3. Results and discussion

3.1 The Stiffness of Sponge

Stiffness is defined as the ratio of the stress along an axis over the strain along that axis in the range of elastic sponge behaviour. Based on this testing, the stiffness found in sponge was 35kPa. The stiffness test was not applied to the peat soil since the physical characteristics (oversaturated) could not be sustains the exerted forces. Thus the sponge was used as simulation having approachable similarity design of stiffness as in the peat soil.

3.2 Moisture Content of Hemic Peat Soil

The average moisture content of the disturbed hemic peat soil sample as shown in Table 2 from the experiment was 72.1% which taken from the site located at Parit Nipah Darat, Batu Pahat, Johor. The average value of this moisture content was less compare to the past researchers (more than 100%) as the temperature was set particularly to control the physical testing done (lab scale) for each foundation (flexible, rigid and mat) within the time period.

Table 2. Moisture content of disturbed hemic peat soil

Test No.	1	2	3
Mass of can (g)	9.687	9.563	9.773
Mass of can + moist soil (g)	44.982	59.454	55.486
Mass of can + dry soil (g)	30.326	38.505	36.233
Mass of water (g)	14.656	20.949	19.253
Water content (%)	71.0	72.4	72.8
Average (%)		**72.1**	

3.3 Critical Analysis in Settlement of Fill Loading Subjected on Sponge Foundation

The analysis subjected to sponge was done in flexible, rigid and mats foundation using the physical modelling box. Generally in this research, the test had been conducted in two different ways of sponge which were:

i. The settlement design on full sponge
ii. The settlement design on half sponge and half solid (Figure 4 and Figure 5)

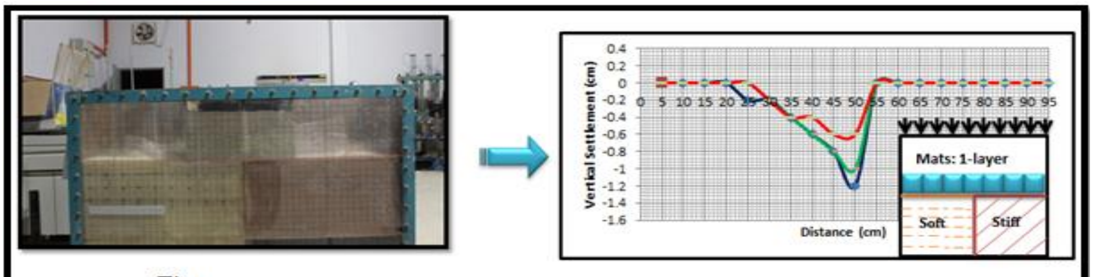

Figure 4. The graphical result obtained from mat's 1-layer.

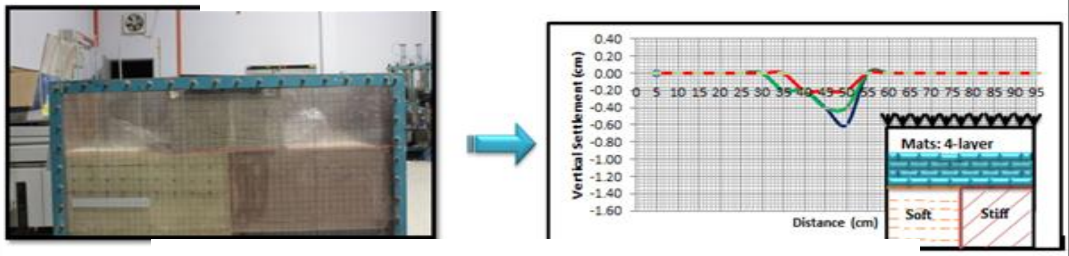

Figure 5. The graphical result obtained from mat's 4-layers.

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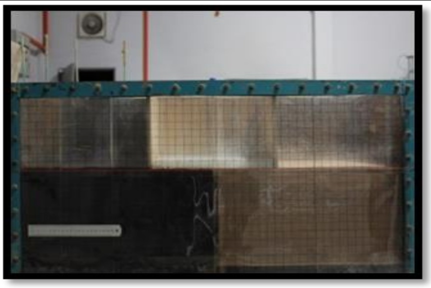
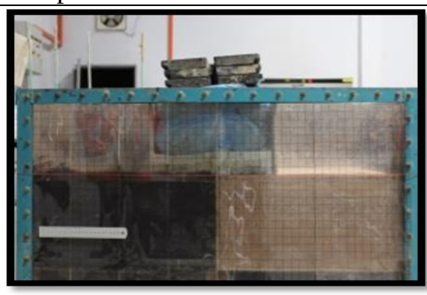
- The mat design with 4-layers clearly has reduced the uneven settlement compare to other foundations (flexible, rigid and 1-layer mats).
- The Mat's effect demonstrated in Figure 5 which shows 50% reduction in settlement that occurs with the normal flexible full design shown in Figure 4.

3.4 Critical Analysis in Settlement of Fill Loading Subjected on Hemic Peat Soil

The analysis had been taken over in flexible, an innovative cellular and innovative cellular mats foundation using the physical modelling box. However during the analysis, it was hard to determine the value in settlement due to the colour of peat soil (dark brown) distinguish the transparency graph. Thus in order to evaluate the settlement occur in peat soil, the observation of analysis was took over at surface area of the physical modelling box shown in Table 3 whereby to predict the total required of mats (layers) to reduce the settlement in peat soil. Particularly the test was conducted on for half hemic peat soil with half solid.

Table 3. The differences in settlement design in foundations (half peat soil).

Foundations	Control Load	Applied Load 500N
Flexible		
Remarks: In the flexible form there is large amount of differential settlement occur as can be seen in the angle in position of loading moving towards inclined		
Rigid		
Remarks: There is differential settlement occur when using uncut piece of innovative cellular mats.		
Mats 3-layers		
Remarks: The settlement is being reduced compared to the others (flexible, rigid and 2-layers) thus according to the prediction if more layers are increase then the level between innovative cellular mats and the solids will become constant or at one line.		

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4. Conclusion and recommendation

As for the conclusion, the comparison in settlement behaviour for both peat soil and sponge was done to achieve the objective of this research study. The settlement has been reduced to 50% by the use of mats in this research.

As for the recommendation, the physical modelling as shown in Figure 6 below can be used in the software modelling in the future. Apparently we can critically analyse this software modelling applied in real condition of field/site (full scale) in reducing and redistributing pressure exerted from loading to the soil.

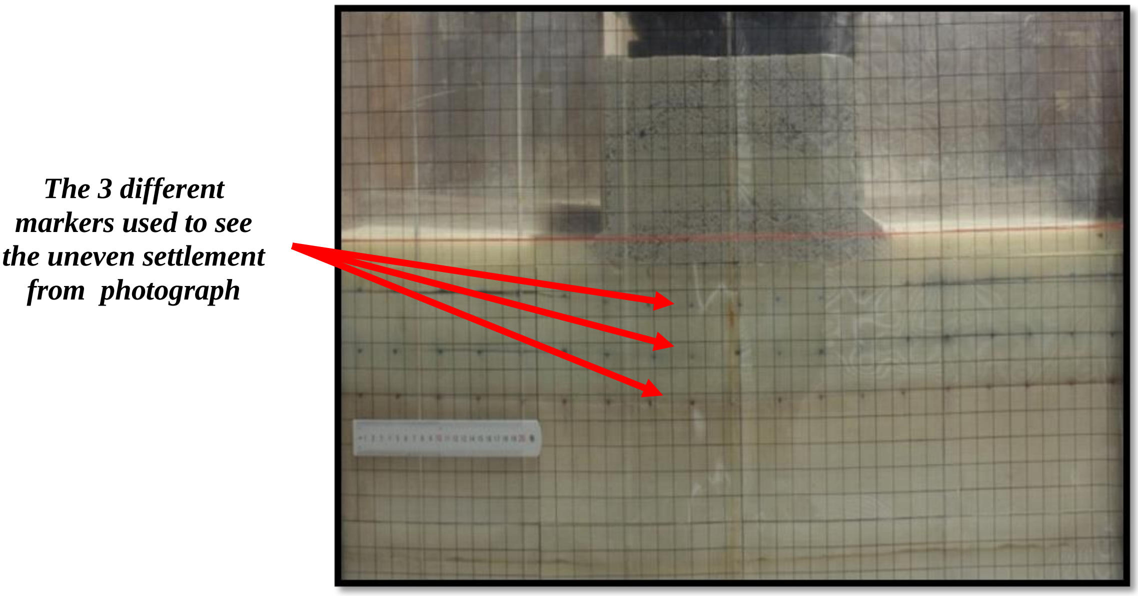

Figure 6. The settlement design/mode shown from the pointed markers in 3 different layers.

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