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Application of GIS Analyzing Settlement Along Pekan-Kuantan Federal Road

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ABSTRACT

Improper geotechnical and geological site investigation done before any construction will contribute to serious problems like settlement. Government not only has been spending billions of money to facilitate public with infrastructures but also the same amount of money for maintenance over the years. Therefore researchers around the world are continuously searching for the best method to compute settlements in soil and engineers too are proposing the best practices in improving the ground before the construction. The main aim of this research is to find out if Geographical Information System (GIS) could be used as the one of settlement analysis tool as well as for engineers in verifying their road alignment design. The Pekan-Kuantan Federal Road has been chosen as the study area and available borehole data was utilized using GIS before relevant analysis was conducted. The output of this research was the establishment of settlement database along the study area which assists the researchers in recommending suitable ground treatment and even proposed a virtual alternative route for this road. It is significantly showed that GIS would serve as the most efficient tool in determining road alignment especially in problematic ground such as peat.

1. Introduction

Located on the banks of the Pahang River 50 km south of Kuantan, Pekan is the royal town of the Malaysian state of Pahang. Being in the largest state in Peninsula Malaysia, Pekan is never kept untouched from development and one good evident would be the recent construction of Pekan-Kuantan Federal Road. Even though Pekan has abundance of peat soil coverage this does not stop the local government to take it as a challenge considering the significant of this project and others for economic reason.

Peat land can be found in many countries throughout the world. According to the survey done by Harlten & Wolski (1996), Canada and Russia are the two countries with the largest areas of peat. From the same survey it is denoted that Malaysia stands in 10th rank in the percentage of national area covered by peat which is 9.4 % or 3.0 million hectares. Table 1 shows the distribution of peat in Malaysia. However most of the peat land is not explored yet for construction and some of it is reserved for agricultural purpose. The peat land in Pekan is one of the best examples that picture the real situation where most of the area is covered by peat soil. It is not well explored because of the problematic soil which hosts certain difficulties in construction of line structures such as roads and drains.

Table 1: Distribution of peat in Malaysia

STATE	AREA (hectares)
Johor	228 960
Negeri Sembilan	6 300
Selangor	194 300
Perak	107 500
Pahang	219 561
Terengganu	81 245
Kelantan	7 400
Sarawak	1657 600
Sabah	86 000
TOTAL	**2 588 866**

Peat is basically organic soil but the matter that differs from organic soil and peat is the percentage of organic content present in the soil. Peat contains more than 75% of organic matters but for ordinary organic soil the percentage of organic content is around 20 % (Huat B.B.K., 2004). Peat is a mass of dark brown or black plant material produced when the vegetation of a wet area is partly decomposed. Peat is used in many sectors such as agriculture, cosmetic, fuel alternative, and insulator industry but in construction sector the properties of peat which has high compressibility and low shear strength turns the peat into problematic soil. Engineers are reluctant to construct on peat because of the difficulty to access the site and other problems related to unique characteristics of peat.
The study area is along the 37 km of Pekan-Kuantan Federal Road as shown in Figure 1 and based on the available boreholes data; types of soil found here are mostly peat, soft clay, sandy and silty. Definitely settlement plays a very strong influence here in relative with the subsurface geotechnical conditions. The first step for reliability predictions is to characterize the subsurface conditions. GIS mapping is considered the nearest simulation of the real world and an addition to the settlement analysis will further provide more accurate results reflecting the actual conditions. Hence the characterization of subsurface conditions and prediction of ground-structure interaction can help avoiding such undesirable damages, costs, and extra effort up to maximum degree.

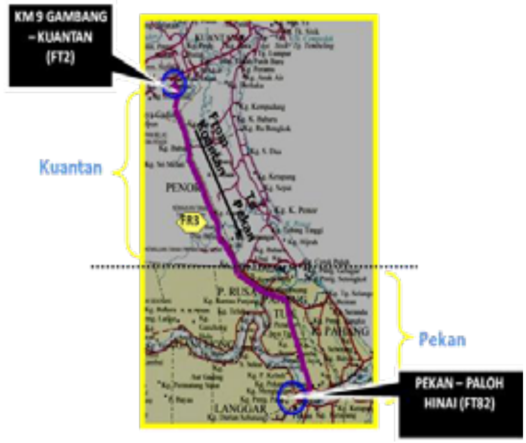

Figure 1: Location of study area

1.2 Settlement

Settlement is the main problem of any building when it is constructed on soft soil like peat. Some settlement is inevitable and depends on the ground conditions whereas some settlements are tolerable. In designing a structure it is common to assume that the foundation will not move. Likewise, if cracks appear in the structure it is assumed that the foundation did move and that was the sole cause of cracking. As loads are applied to buildings or road, an "immediate" settlement occurs as a result of instantaneous compression of the soil. Most of the immediate settlement may be accommodated within the structure as it is built, and fortunately much of the differential movement occurs at this stage.

Settlement is defined as the vertical displacement of the ground due to increasing effective stress (Rodrigo Salgado, 2008). Predicting settlement is important even though no rupture is imminent, for three reasons:

1. Damage to the road structure
2. Utility of the structure
3. Appearance of the structure.

When a saturated soil is subjected to a steady pressure due to the weight of overlaying soil or to the load from a foundation or to an increase in effective stress because of lowering the water table, its volume will be decreased. Since both the soil particles and the water in the voids may be considered incompressible at the sort of pressures encountered, the change in volume can only occur if water is forced out of the voids thus reducing their size and enabling the solid particles to become wedged closer together.

This process is known as "consolidation" and the vertical downward displacement brought about by such a volume change is called "primary settlement" (Yenigul, N. B., 2000).

1.3 Settlement Prediction

The primary data collected includes the location of borehole, types and engineering properties of soil, and settlement rate. All of the data were obtained from available soil investigation report and Figure 2 a- d shows the prediction of settlement rate using graphical method of Asoka.

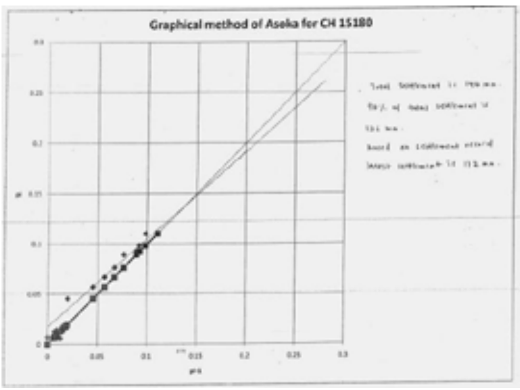

Figure 2a: Settlement rate using graphical method of Asoka CH 15180

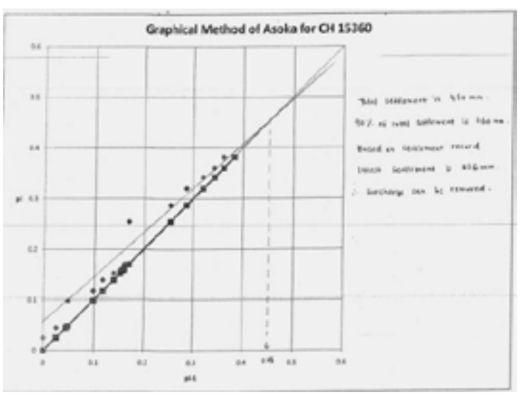

Figure 2b: Settlement rate using graphical method of Asoka CH 15160

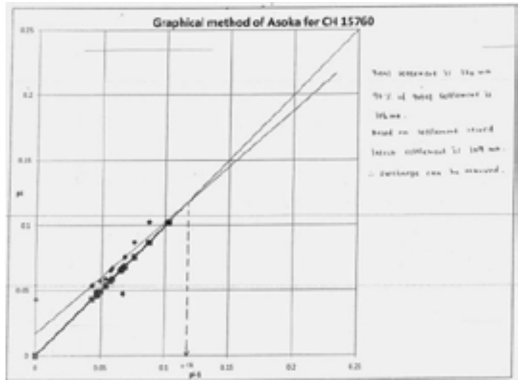

Figure 2c: Settlement rate using graphical method of Asoka CH 15760

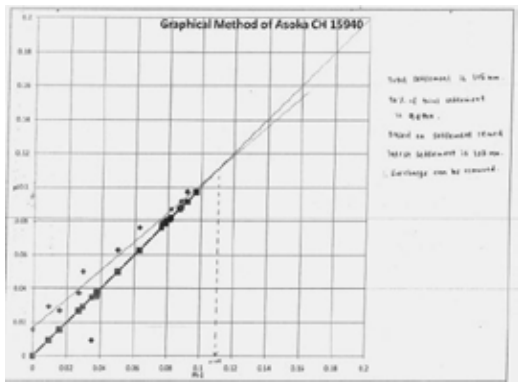

Figure 2d: Settlement rate using graphical method of Asoka CH 15940

2. GIS Layers

The GIS layers were developed in order to identify entities, attributes and relationships between variables. Boreholes locations are shown in Figure 3. The following attributes were used in GIS layers: *Shape:* The types of shape of the specific borehole (Point).

- *Point Id:* The identification number of the borehole.
- *Type of soil:* Soil classification (clay, sand or silt).
- *Rainfall erosion index:* The annual precipitation rate at study area.
- *Boreholes coordinate:* The specific location of every borehole.
- *Soil parameters:* The value of soil properties (bulk density, moisture content, plasticity index, undrained shear strength, coefficient of consolidation and unit weight).
- *Total settlement:* The value of settlement for every borehole.

- *Ground Treatment:* The suitable treatment surrounding borehole.

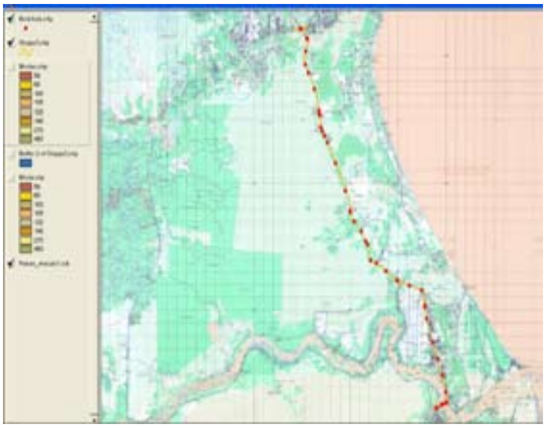

Figure 3: Borehole locations at the Pekan-Kuantan Federal Road

3. Results and Discussions

Settlement database was established using data which were converted into GIS format. The establishment requires the information and data to be merged in the form of different layers. Therefore, it will form the new map with new road database.

In this research, six layers were merged together in order to create settlement database. The first layer contains the coordinate of boreholes along the road. The second layer contains the lines along the road. The third layer is the values of settlement distribution predicted. The fourth layer is the buffer of shape, while the fifth layer is the settlement prediction area and the last one is the topography map. By combining the entire layers, the objective of this research is achieved.

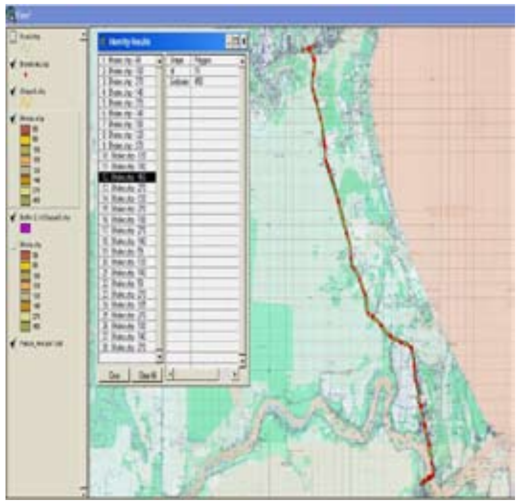

Figure 4: Settlement database on topographic map

The length of the road is divided into 47 lines where the total length is 37 kilometers. Some of the lines represent two kilometers and three kilometers length, thus all the lines are in different length.

Every red point represents a borehole and polygon represents settlement rate surrounding the borehole and road. Gap for every settlement rate were showed in polygon. Each polygon is edited to include with the total settlement rate based on graphical method of Asoka. Figure 4 shows the result for the GIS format of total settlement rate. Every polygon contains the values of settlement along Pekan-Kuantan Federal Road.

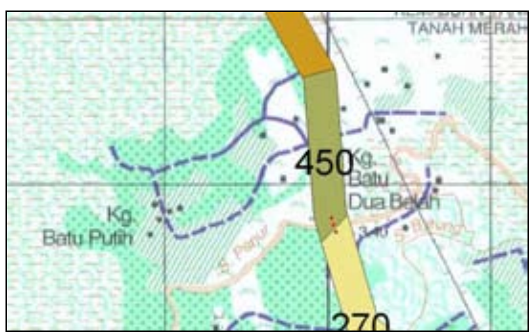

Figure 5: Highest settlement area (critical area)

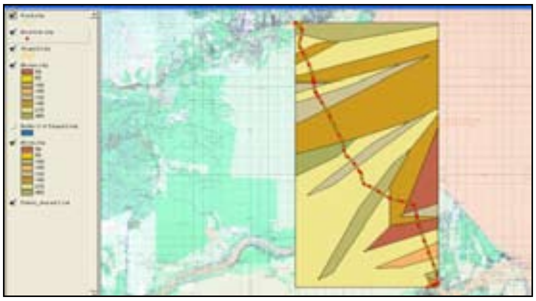

Figure 6: Prediction of settlement around study area

3. Proposed New Route

In this section, authors have proposed a solution for this problematic route at the study area. The problem is due to the type of soil existed there and the amount of settlement predicted. Besides recommending the suitable ground improvement method, the other solution is to build a new road to detour from the critical area. The following figure shows the new layout for the suggested road.

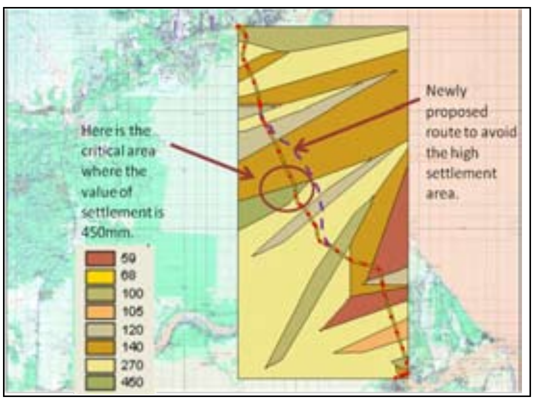

Figure 7: Layout of the new road

3.1 Ground Improvement/Treatment

The result of the settlement database using GIS technique and site investigation indicates that ground improvement is required at many stretches where the in-situ soil conditions are unsuitable to support the embankment and other applied loads. Selection of the ground improvement options is governed by the following factors:

- Height of embankment fills.
- Thickness of the unsuitable soil material deposits.
- Magnitude of settlement if no treatment is carried out.
- Initial shear strength of the unsuitable soil deposits.
- Stability of embankment fills.
- Cost effectiveness.

Based on the above factors, the following methods of ground treatment were considered for various types of ground conditions:-

- Ground Treatment Type A (removal and replacement with sand)
- Ground Treatment Type B (6m length prefabricated vertical drain and surcharging)
- Ground Treatment Type C (12m length prefabricated vertical drain and surcharging)
- Ground Treatment Type D (piled embankment)

4. Conclusion

Improvements of road management system are acutely a very complicated task requiring coordinated actions and interventions at different stages and levels to maximize their effectiveness. Therefore, Geographical Information Systems (GIS) is proven to be effective in analyzing settlements and making decisions related with new road constructions. In conclusion, the visualized model produced will be allowing the exchanges, organize, store, manage and retrieve the information for decision support in settlement analysis management. GIS model could also replace the manual method to keep all the records regarding the observation on the high settlement rate which need maintenance or renovation. Meanwhile, the GIS model will ease the work process significantly compared with the manual method it also can reduce cost for modeling and modifications.

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