SITE INVESTIGATION AS A GEOTECHNICAL FORENSIC TOOL FOR ROAD EMBANKMENT PERFORMANCE EVALUATION

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ABSTRACT

Forensic studies are attempts to find solutions and to uncover the causes of the thing that has happened by relating them to certain standards stipulated by the relevant bodies. A forensic investigation is the process by which the forensic engineering team gathers the necessary information to determine the probable cause of failures that occurred. There is a methodology for investigative procedures that can be used when determining the cause of failure. This project focused to rural road embankment in rural area. The growth percentages of rural area will increase every year which mean this area will continue to increase in population thus affecting the role of the rural road system. The project has to be done in Batu Pahat soft clay located at RECESS site in UTHM campus. RECESS is an acronym of Research Center for Soft Soil; it was established in order to carryout field trials and adopts this as a national center for soft soil research in Malaysia. At the site, a full scale rural road embankment model was constructed with two (2) types different reinforcement. They are Rawell Geosynthetic Clay Liner (RGCL) and Woven Geotextiles(WG). The samples were taken for the types of different reinforcement and control section. The samples were core for further lab testing includes soil and aggregate test, asphalt test and geotechnical testing. Field testing was done at RECESS site. The instrument were used for field testing was Dynamic Cone penetrometer (DCP), Electricity Resistivity test equipment and Ground Penetrating Radar (GPR), On site testing includes several measurement like surface deflection, strength of layers and thickness survey. The end of this project, the author was define that data analysis can determine what the distress cause is by and provide the best selection of treatment that can stop the failures.

Keywords: Forensic Investigation, rural road embankment, full scale, Batu Pahat Soft Clay, RECESS Malaysia.

INTRODUCTION

In 5 years previously, local authorities in Johore especially Batu Pahat Public Work Department (BPPWD) received many reports toward road damage. According to Azman and Masirin in years 2000, about 20%-30% of total roads in Batu Pahat district experienced varieties type of failures; from surface failures to structural failures (Jestin, 2006). After many years, terminal serviceability may occur sooner, than more roads defect will reveal. Maintenance and rehabilitation cost imposed high financial burden to road agencies particularly when rural roads are concerned. If the cause of failure is confined to the upper layers, then the repair can be relatively inexpensive; however, if the problems are related to structural deficiencies in the base or subgrade, then much more extensive and expensive repairs will be required. From the observation, it should be highlight that cracking was major distress found in Parit Raja rural road compared to the other types of distress. Commonly cracking were apparent not solely but rather associated with large surface deformation. Batu Pahat Public Work Department (BPPWD) is concerned about their road and has applied extensive seal coats, thin overlays and other types of surface treatments to preserve and/or improve the surface condition. Those measures provide a temporary improvement of the surface condition, but they do not provide the remedy to any structural deficiency associated with the pavements. As a result, the overall pavement condition keeps deteriorating because the structural deformation of pavement layers and the subgrade, even though surface treatments have been applied periodically.

MATERIALS AND METHODS

The first field observation has been conducted for this study in September 2006 in order to survey failure embankment and pavement distress on full scale trial rural road embankments constructed on soft clay. The section was investigated had experiencing severe surface deformation associate with longitudinal cracking. The distress can be seen along the roads especially at section were loaded with static and dynamic loading. Any location where the deflections are higher will be trench in order to study the cause of cracking and deformation. Trenching performed to verify the thickness and condition of bound or unbound layers or determine which layer(s) are deformed and cracked. Comprehensive tests for the second trip involved in situ testing devices, such as the dynamic cone penetrometer test (DCP), ground penetrating radar (GPR), and coring, samples was cored from test site and the samples was tested in highway and geotechnical laboratory.

OBSERVATIONS AND ANALYSES

Levelling Survey

Levelling survey was carried out to understand the surface and water level of the trial rural road embankment. The purpose of this levelling survey is to determine a movement and deformation of surface. The method carried out from April 2007 until July 2007 which means, the data was presented for 4 month. From the parameters recorded by level surveying, the long section of trial rural road embankment was plotted. The author found that the road surface had a smaller movement and deformation for every month. Long section was plotted using 3.00m as a datum. The weaker subgrade causes a movement and deformation of road surfaces. Besides, the author cannot be find out the exactly causes of failures from levelling survey. In this stage, only the surfaces movement may identify.

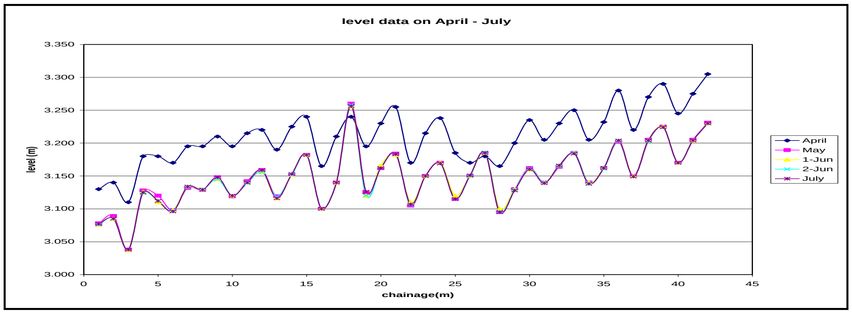
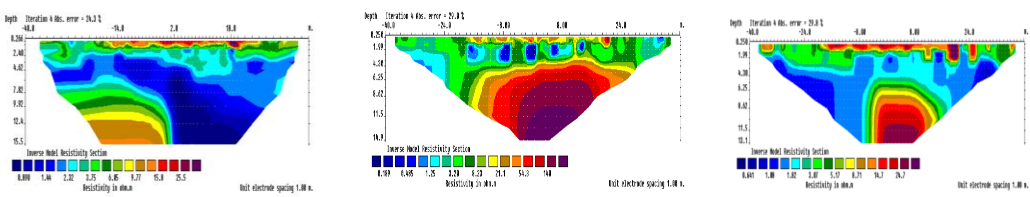


Figure.1: Graph showed that different level of trial rural road embankment

Electricity Resistivity Test Method

For this research, geophysical survey was conducted using electricity resistivity test method and the analysis employed were Schlumberger, Wenner and Gradient protocols. Geophysical surveys can yield valuable information about sub-surface features. There are three methods of protocol used to analyse the subsurface condition in the research area. These various results are as shown in the followings:



(a) Gradient protocol **(b) Schlemberger protocol** **(c) Wenner protocol**

Figure 2: 2-D images produced using the various protocols after the geophysical site investigation tests

The analyses of subsurface condition only considered 2 meter depth from the surfaces. By referring 2D image from Gradient Protocol, the different color of layers indicate the layer’s resistivity which is in the range between 9.77 ohm.m (ohm meter) to 25.5 ohm.m It show that imported soil have a different layers compared to the original soil. While according to 2D image from Schlemberger Protocol, the range of resistivity giving us a value from 20 ohm.m to 140 ohm.m. It may be shown this range consists of five colors representing a type of soil which have high resistivity compared to Gradient Protocol. The third data was presented by Wenner Protocol resulting of resistivity value from 14.7 ohm.m to 25 ohm.m. 2D image outcome from Wenner protocol is able to shown the tenuous layers may give a detail and clearly appearance of subsurfaces condition. The yellow layers shown the 2D image for each single protocol were separated original soil and imported soils, it was believed that the reinforcement was installed before the road pavement. There have a different value between Schlemberger protocol compared to Gradient protocol and Wenner protocol, it because data presented by Schlemberger was including the calculation and measured data or image. The input data using Schlemberger protocol less than the data collected from the others protocol. The value from both of Wenner protocol and Gradient protocol appear close differences. To understand detail layers information, boreholes or drilling activity must be done in order to take the undisturbed and disturb sample for further lab testing of soil properties.

GPR Result

Initially, the GPR used in this research was to observe pavement layer thickness and subsurface condition as well as to observe the level of water table. From GPR testing the researcher get the visualization data to complete observation method. The observation was done simply by pushing the instrument along the survey roadway from CH0 to CH65. The data acquisition at site was shown in figure 3 below which taken from the actual observation process using the Win_SpiView software. During data acquisitions, the researcher was identifying the location as indicated at the bottom part of the picture so that can recognize where the data were taken. However, due to inconsistency in reflections, it is critical to verify the interpretations. Therefore, trenching results was used as reference; it is then possible to interpret the GPR data. The thickness results are recorded in figure below.

Layer	**GPR**		
	WG	**RGCL**	**UNR**
AC	80	80	20
Base	120	120	120
Subbase	120	120	120

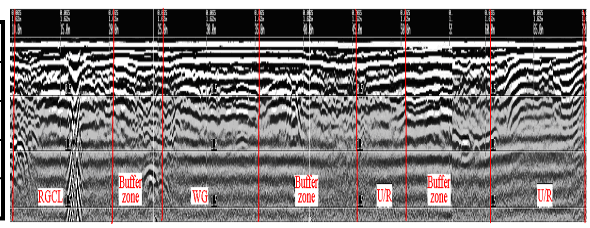


Figure 3: The thickness obtained from GPR observation and subsurface features using GPR method

Dynamic Cone Penetrometer (DCP) test results

The DCP instrument measures the penetration per blow into a pavement through each of the different pavement layers. A DCP test was conduct at site area to evaluate in situ shear strength of materials. Beside the strength, DCP also could determine the base and subbase layer thicknesses. These tests were performed on the same location as coring test because the DCP measure the structural properties for unbound granular material. Therefore, the asphalt layer needs to be cored first. Therefore, there will be 6 DCP data obtained in this test. 2 locations of DCP data were taken at WG, RGCL, and unreinforcement area. The table summarized the thickness layer which computed from the graph. The DCP testing confirmed that the subgrade layer was weak; in fact the DCP penetrated the subgrade about 300mm to 400mm after 5 times drops of the load and its penetration rate range 60 to 80 mm/blows. The base layer poses low penetration range from 4.5 to 5 mm/blows which considerably as good strength. Decreased PR and therefore with the indication of increased strength (Gabr, 2000). Although the stiffness of the all layer are varies from location to location, the modulus values are generally higher than minimum design specified by JKR. Modulus from location was installed reinforcement were the highest compared to the unreinforcement locations reflects that the CBR for reinforcement location is the highest. It is like a trend that the strength and the stiffness become lesser when approaching near the deteriorate area. The California Bearing Ratio (CBR) and modulus values computed from the DCP penetration rate, using Equations 1 and 2 are given in Table 2. This equation normally used by various researchers (Gabr, 2000 and Chen et al, 2000).

$$CBR = \frac{292}{PR^{1.12}} \quad \text{------(1)} \qquad\qquad E(Mpa) = (17.58)(CBR^{0.64}) \quad \text{--------(2)}$$

Table 1 : Layer thickness obtained from DCP test.

locations	**Subbase**	*Base layers*
Unreinforcement 1	320	230
Unreinforcement 2	180	180
Woven Geotextiles 1	270	170
Woven Geotextiles 2	360	180
RGCL 1	340	162
RGCL 2	350	60

Table 2 : Dynamic Cone Penetrometer Modulus and CBR using equations (1) and (2)

Location	**Base**		**Subbase**		**Subgrade**	
	CBR	**Modulus elastic, E (Mpa)**	**CBR**	**Modulus elastic, E (Mpa)**	**CBR**	**Modulus elastic, E (Mpa)**
Unreinforcement 1	14.75	98.41	7.38	63.18	3.90	42.00
Unreinforcement 2	36.33	175.22	14.07	95.48	4.32	44.84
Woven Geotextiles 1	34.11	168.29	6.47	58.08	4.46	45.77
Woven Geotextiles 2	24.92	137.66	7.69	64.87	5.53	52.53
RGCL 1	28.04	148.46	2.58	32.24	6.47	58.08
RGCL 2	39.3	184.26	7.94	66.21	5.22	50.62

CONCLUSION

Based on the site investigation and observations, the authors hope have identified factors that may contribute to reduce the maintenance cost of roads constructed on soft soil, determine the distress causes and provide the best selection of reinforcement for rural road embankment constructed on soft clay. The outcomes of this research are expected to enable better understanding of soft soil-embankment interaction during post-construction. From analyses and observations, the authors found that there were movements and deformations on the road surfaces. Although the results were often more qualitative, resistivity method presented the exact sub-profile conditions of the site. However, another stage of site investigation can be conducted to gather further information about the site and this will complete the site investigation procedure as stated in accordance to Clayton et al (2005). Although certain work has already been accomplished in this research, much still remain to be explored in order to ensure the success of a functional forensic system.

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