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A STUDY ON THE USE OF POLYURETHANE FOR ROAD FLOOD DAMAGE CONTROL

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ABSTRACT: The strength of subgrade soil or road foundation could influence the design of road pavement structures. Flood can be one of the causes of weakened subgrade and consequently road damages. Since the condition of subgrade layer is critical in the road pavement stability, a preliminary study was carried out to ascertain the use of polyurethane insertion as a stabilization mechanism in road subgrade. This study was conducted based on two types of soil that are usually used as soil embankment in road construction. California Bearing Ratio (CBR) test was conducted on the various categories of soaking days and repeated submerged conditions to determine the strength of subgrade soil with and without polyurethane layer. It can be concluded that polyurethane layer can be used to increase or maintain the strength of subgrade soil from the inundation effect.

Keywords: Subgrade, Road, Flooding, California Bearing Ratio (CBR)

1. INTRODUCTION

Floods have great impacts on road infrastructure and people as their activity may be disrupted and the impacts, in most cases, can last for more than one week. In the coming years, climate change could make the situation become more challenging [1]. Floods are also among the most costly natural disasters in terms of returning occurrence, economic loss and human suffering. These flooding damage the roads, environmental surrounding, and livelihood. The impact of the flood can take the long term effect in maintenance works since the whole range of civil infrastructures are usually involved. The continuous flood submersion to the roads would bring damage on large part of any city or village infrastructures [2]. However, damage to road pavement and roadway could create disconnection of people movement and emergency supply or evacuation works. Road subgrade is the most prone to the flood effect because it is at the lower level of road structure, having the largest exposure to flood. Ghani et al. [3] found that the CBR values for subgrade strength decreases due to the higher number of inundation days of the subgrade soil.

Subgrade soil can be strengthened by the stabilization agents such as cement, lime and fly ash. Besides the three agents, polymer or polyurethane has also been used to stabilize sand clay mixtures in the soil slope erosion [4]. The impact of flooding can be disastrous to the infrastructure and the environment. On top of that there will be huge expenditure for the rehabilitation process and it may take some time to make things back to normal. Soil stabilization is one method for soil improvement which help to improve the subgrade soil strength hence reducing the impact of flooding on road infrastructures. There are few types of existing subgrade improvement using chemical, geotextile and mechanical. Poor quality of the subgrade soil can be improved by the treatment of the soil using stabilizing agents cement or lime [5], [6]. For example, soft clay mixed with cement will strengthened the subgrade because cement and water react to form cementitious calcium silicate and aluminum hydrates which can bind the soil particles together [7].

Geotextiles can also be used for subgrade stabilization because it can maintain physically the integrity of pavement layer boundaries and it enables water to move in an unrestricted manner. Subgrade alone, when it is weak, cannot support layer interface because of the interpenetration of soft subgrade with granular layer under the high traffic loading. As solution, geotextiles can be placed at an interface of the soft subgrade and granular layer to prevent the two materials intermixing and function to stabilize the interface between two materials and enable the granular layer to maintain the compacted strength [8].

There are many application of polyurethane in the manufacturing and construction industry. Polyurethane has been used to improve the safety and performance of railway track infrastructure due to the stiffness and ductility [9] and has become a solution to the settlement problem with the injection of polyurethane to the pile and slab in order to replace the conventional underpinning pile [10]. Polyurethane has also been used to fill void in the soil and reduced settlement issues [11].

The advantage of polyurethane is it is durable and have shorter time to complete remediation which may gain 90% compressive strength within 15 minutes from injection or spraying. In order to determine the feasibility of using polyurethane in road foundation strengthening, there is a need study its behavior and how it can be applied in case of road subgrade. One possible application is illustrated in the following Fig.1.

Fig. 1: Polyurethane layer by spraying or preformed block

2. MATERIALS AND METHOD

The use of polyurethane is simulated in the lab using CBR mould and test. Two (2) types of commonly used or found soil as subgrade layer were used in the CBR test. Details of the soils are shown in Fig.2, 3, 4 and 5.

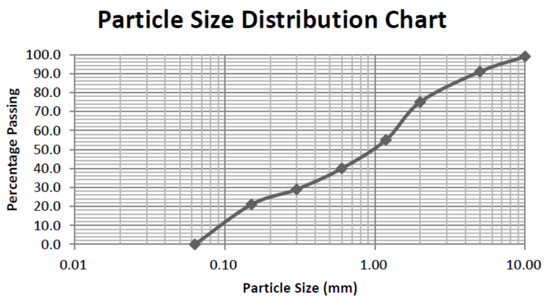

Fig 2: PSD for Soil 1

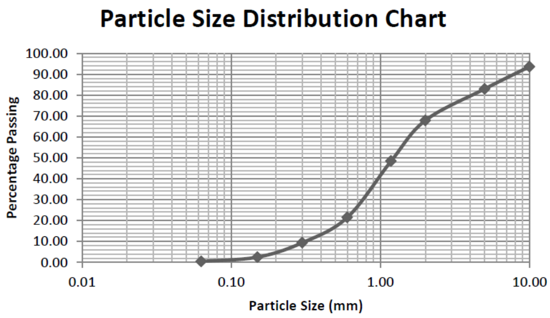

Fig 3: PSD for Soil 2

Fig 4: Soil 1

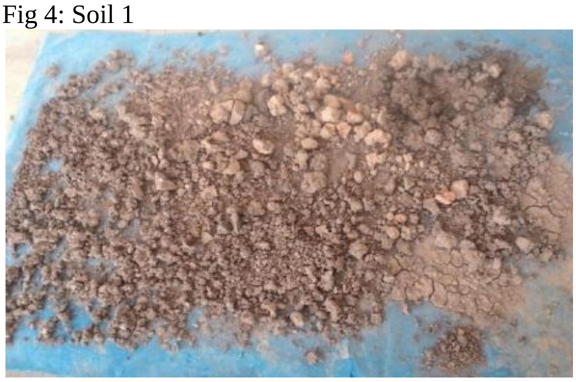

Fig 5: Soil 2

Other basic properties of the soils used in this study are shown in the following Table 1.

Table 1: Basic Properties of Soils

Properties	Soil 1	Soil 2
Specific Gravity	2.64	2.60
Maximum Dry Density (kg/m3)	1964	1510
Plasticity Index	Non Plastic	28.5%
Grading	Well Graded Sand (SW)	Poorly Graded Sand With Clay (SP-SC)

2.1 The Polyurethane

The polyurethane layer used in this study was produced from mixing two (2) compounds namely polyol and polyisocyanates at a ratio of 1:1.2. The compound that can be obtain from local supplier is shown in Fig 6 below.

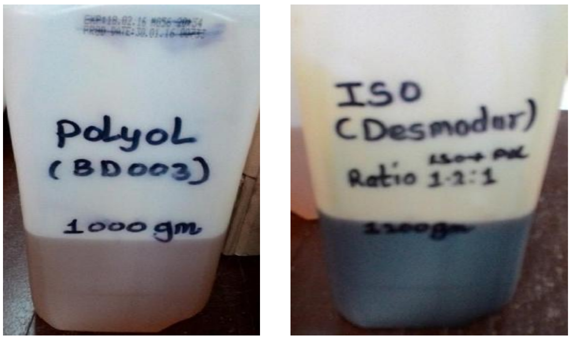

Fig 6: Mix ratio of polyurethane compounds

Cured polyurethane in a PVC mould were then cut into sizes as shown in Fig 7 for placement in the CBR mould together with the subgrade soil samples as shown in Fig 8.

Fig 7: Polyurethane

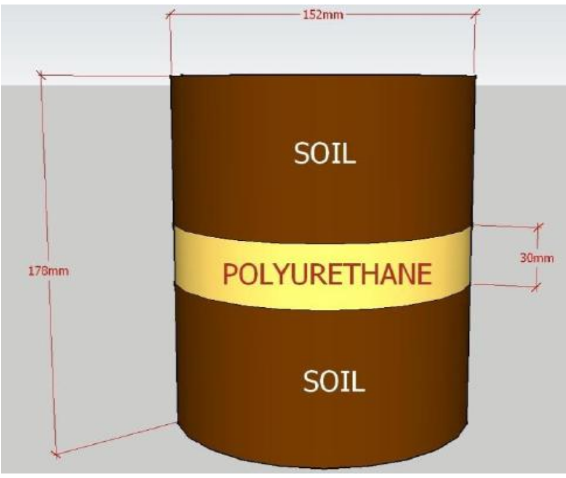

Fig 8: Placement of Polyurethane Layer

2.2 Specimen and Test Preparation

CBR specimens with and without polyurethane were prepared in the lab. Altogether 24 specimens were prepared from Soil 1 and Soil 2 (12 each). The specimens were intended for control, continuous soaking and repeated submerge conditions. Fig 9 shows specimens kept under water.

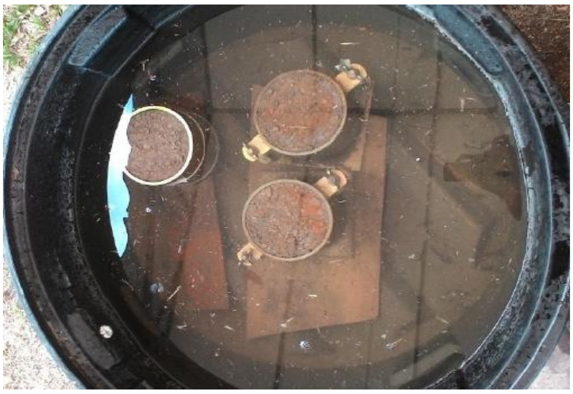

Fig 9: Specimen under water to simulate flood

Specimens were kept under water according to the specified inundation period of 1, 3, and 7 day duration. Another set were repeatedly inundated for one hour only on day 1, 3, and 7 to simulate repeated flood submerge.

California Bearing Ratio (CBR) tests were conducted on all the samples of soil according to BS 1377 using instrumented CBR equipments.

3. RESULT AND DISCUSSION

3.1 Soil 1

Fig 10 shows the difference between the strength of the soil that unsoaked and soaked conditions for sample of soil that normal and there is an additional of polyurethane. The samples of soil left to soak in water for different days which are 1, 3 and 7 days. The graph shows the CBR value of the sample of soil that does not soaked is higher than the samples of soil that soaked. This is because the saturated period of the soil sample. The CBR value to the sample of soil that not immersed is 50.35%. The result CBR values for the samples of soil that soaked for 1, 3, and 7 days is 3.65%, 6.45% and 3.8% respectively. These results show that the presence of water during the immersion causes the degradation of the soil sample.

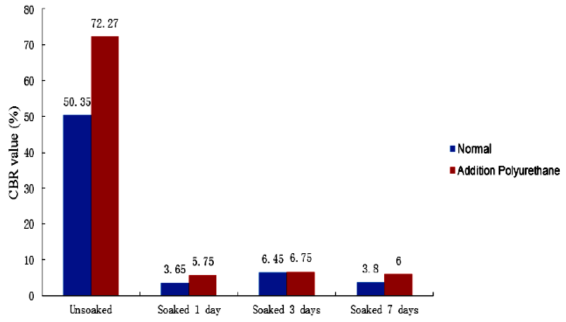

Fig 10: Inundation days and CBR strength (Soil 1)

However, with the presence of polyurethane in the soil sample, the CBR value can be increased slightly. This is means the strength of soil can be increased. For the sample that not immersed in the water, the CBR value is 72.27%. It shows a significant increase to the soil sample. Besides that, in the 1 day of soaked condition, the value of CBR rise from 3.65% to 5.75%. On the other, CBR values for soil sample 3 days of soaked is 6.75% and for 7 days of soaked is 6%. The CBR values for three samples with polyurethane in the soaked conditions have shown higher than the CBR values for normal samples. It can be concluded that polyurethane can help to maintain or increase the strength of the soil.

Graph bar in Fig 11 shows the comparison on the soil samples containing polyurethane between two different situations which is repeated soaked and unsoaked conditions. The soil samples are soaked for 1 hour at Day 1, Day 3 and Day 7.

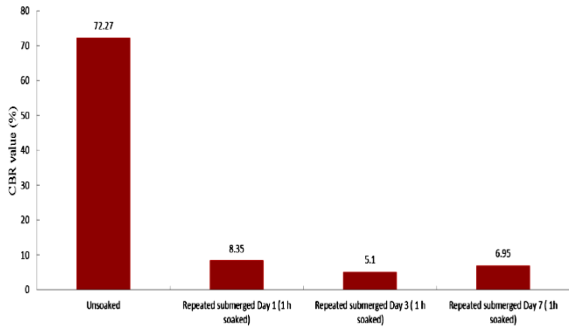

Fig 11: Repeated submergence CBR (Soil1)

The CBR values on the bar chart show the different patterns of the result. It shows that the result on unsoaked condition is 72.27% and for the repeated submerged condition for 1 hour on Day 1, Day 3 and Day 7, the CBR result is 8.35%, 5.1% and 6.95% respectively. In this repeated submerged case, the CBR value was reduced on Day 1 and the value subsequently also reduced on Day 3 compared to the unsoaked sample soil. It can be seen that the CBR values are compatible with the continuous inundation specimens from Fig 9 before.

3.2 Soil 2

Fig 12 shoes the comparison of the CBR value for the soil sample that contains polyurethane and the normal based on the two different conditions which are for unsoaked and soaked condition. For the normal sample soil, the bar graph shows the CBR value for unsoaked condition higher than the CBR value to the soaked conditions. The strength for unsoaked condition soil sample is 44.39% while the CBR value for the soaked condition for 1, 3 and 7 days is 4.3%, 1.7% and 1.3% respectively. The strength of soil tends to decrease due to the inundation of the days.

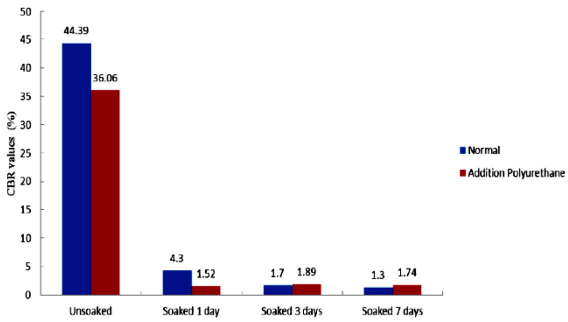

Fig 12: Inundation days and CBR (Soil 2)

However, for the soil sample that containing polyurethane, CBR value for unsoaked condition seen as 36.06% which is obviously higher than CBR value for soaked conditions. In the graph, the CBR value for 1 day soaked is 1.52%, while CBR value for 3 days soaked is 1.89% and for 7 days soaked, the reading of CBR is 1.74%. Generally, the value of CBR for soil samples in 3 and 7 days soaking period is increase.

Subsequently, in Fig 13, the graph shows the result of Soil 2 samples for CBR value for control and repeated submerged sample containing polyurethane. The repeated submerged sample is soaked for 1 hour on Day 1, Day 3 and Day 7. The control sample shows the highest result with CBR value of 36.06% compare to the repeated submerge sample. CBR value for the repeated submerge samples are decreasing respectively from day 1 to day 7 in which the result are 2.35% on Day 1. Then it is reduced to 1.65% on Day 3 and 1.30% on Day 7. So, it can be seen that CBR value become lower when the soil was submerged again and again under water.

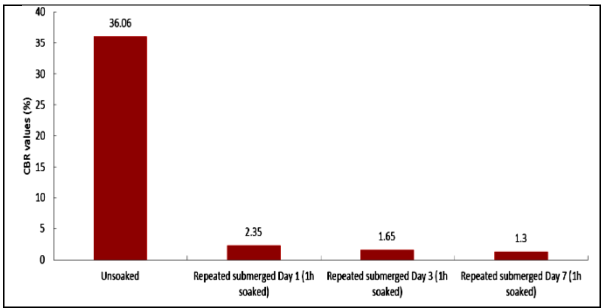

Fig 13: Repeated submergence CBR (Soil 2)

3.3 Other Observation

It is also important to note that the movement of the CBR plunger downward is also contributed by the compressible effect of the polyurethane layer itself. This can be observed when the soil and the polyurethane layer are removed from the mould as shown in Fig. 14 and 15. If this movement can be predicted and control, the ultimate actual subgrade strength improvement is actually higher than what is shown above.

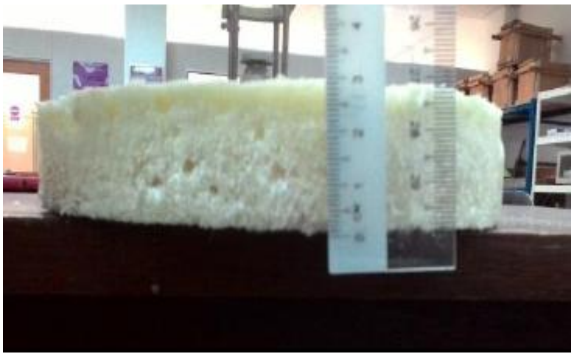

Fig 14: Polyurethane layer before test

Fig 15: Polyurethane layer after test becomes thinner

4. CONCLUSION

This experimental study had been conducted in order to determine the strength of soil sample containing polyurethane and its capability to maintain the strength when the soil samples are kept in different inundation conditions. From the result of this study, it can be concluded that the soil samples that have been kept in longer duration of inundation tends to loss the strength as expected. Polyurethane that was placed in the soil samples and tested in the different days of inundation indicated that it can help to increase and maintain the strength of the soil. The reduction of subgrade strength once it is inundated can be very significant. In this study, polyurethane layer helps recover at least 3% of the strength loss due to inundation.

However, there is one issue that requires further investigation. The issue is about the compressibility of the polyurethane layer under load. This issue must be comprehended and resolved before any actual application on site.

5. ACKNOWLEDGEMENTS

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