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To cite this article: Roziawati Razali and Mohamad Shukor Che Malek 2019 *IOP Conf. Ser.: Mater. Sci. Eng.* **512** 012006

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The usage of cement for soil stabilisation in construction of low volume roads in Malaysia

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Abstract. There are about 25% of the total road networks in Malaysia is an unpaved road which is contained gravel or earth road [1]. These are commonly referred to as the low volume roads or unpaved rural road or agriculture roads which required a very minimum standard of design and construction due the low traffic impact and function of the road as an accessibility tool to the local communities. Difficulties in transporting of the materials to the construction site due to the distance from the quarry or construction material source do occur together with the requirement of suitable machinery. Soil stabilisation was identified as an alternative method to facilitate the design and construction requirement in achieving the implementation of the project where respect to cost, time and quality. Currently, soil stabilisation method was not popular in Malaysian construction industry players especially among road designer because the conventional method of pavement design always been the most priorities. Perhaps this may due to the absence of the specification purposely for soil stabilisation works. This paper will present the Malaysian experiences of implementing cement as soil stabiliser in road construction project for rural and low volume roads. The study had been conducted in the road construction project of Jalan Pos Sinderut, Kuala Lipis, Pahang. The scope of the study covers all the stages that involved in the implementation of soil stabilisation using cement this project including design, procurement, and construction.

1. Introduction

There are about the total of 216,837 kilometers of roads length in Malaysia including federal and state roads. From this total length of road, there is 52,801 kilometer of unpaved roads that consist of earth and gravel roads [1]. Majority of the roads are falling into the low volume roads category and usually surrounded by rural development as it promotes access to economic and social services, generating agricultural income and productive employment. Long-term performance of pavement structure is significantly impacted by the stability of the underlying soil usually refer to in-situ subgrade that often not achieve the required level of performance under traffic loading and environmental demands [2]. Soil stabilisation can be used to treat the several inches of soil or aggregate surface or other properties of the in-place soil that not achieves the required level of anticipated traffic. Soil stabilisation method also helps to reduce the construction cost by reducing the hauling and transportation of import materials on site due to recycling of the existing materials. The construction of soil stabilisation also required the minimum type of construction machine so that the problem of accessing the machine to the construction site especially at the remote area will be ease.



Basically, soil stabilisation is the alteration of any inherent property of a soil to improve its engineering performance. It is the treatment of natural soil to improve the engineering strength and properties [3]. The most commonly used stabiliser in road construction has been traditionally cement, lime or asphalt products but due to the improvement and innovation of the product by the industry, the non-traditional stabiliser product was developed such as chloride, resins, sulfonated oil, synthetic polymer and various biological enzymes[2],[4].

Currently, the used of soil stabilization in Malaysia is still at the initial stage and not so common compared to the conventional construction method such as using crusher run and others typical road construction materials. The application of soil stabilisation in road construction was still limited to the certain purpose maybe due to the deficiency of the contractor's competency, uncertain about the effectiveness of the technique for the large scale of project and also lack of the suitable machinery for the purpose of soil stabilisation works. Application of soil stabilisation method in Malaysia usually for construction of estate or plantation roads and rural road but not in major roads. The roads were designed and constructed based on the low traffic volume but sometime it will do subjected to heavy load. Due to the benefits of having stabilisation technique is able to increase the existing subgrade strength with economical cost, the government of malaysia through public works departments together with ministry of rural and regional development has decide to use the method in the road construction for the rural area. The construction of the road using soil stabilisation technique was studied and monitored to identify the suitability of the method, the effectiveness of application and the performance compare to conventional method. The study also managed to observe and record all the activities included during planning, designing, procurement, and construction.

1.1. Objective of the study

The objectives of this study are as follows:

- i. To identify the effectiveness of using soil stabilisation method in road construction for low volume and rural road.
- ii. To observe the preferable of machinery to be used in soil stabilisation works in the rural area.
- iii. To identify the performance of soil stabilisation compared to conventional technique.

2. Background of the project

The Project of Menaiktaraf Jalan di Pos Sinderut, Dun Jelai, Cameron Highland, Pahang was one of the projects in the 10th Malaysian Plan under the provisions of the Ministry of Rural and Regional Development. The Public Works Department has been appointed as an implementor for the project. The scope of the project has comprised the upgrading of 35 kilometers of an existing road according to JKR R1 Standard. An existing road condition was earth roads without proper drainage and its result to the severe damage on road surface condition and has poor driving quality. This existing route is used by indigenous people as a medium of communication which is only suitable for pedestrians, motorcycles or four-wheel drive vehicles. Figure 1 below showed the existing road conditions at the project site before the construction.



Figure 1. The condition of an existing road before construction.

The project site is located in Kuala Lipis District, Pahang Darul Makmur as shown in Figure 2. Through the result of in situ California Bearing Ratio (CBR) that had been conducted on the existing subgrade before start the construction works, it was identified 12 locations of soil stabilisation as showed in Table 1 and Figure 3.



Figure 2. Location of the project.

The selected sections of soil stabilisation are represented as the lowest subgrade value of CBR strength. Site investigation including mackintosh probes, hand auger was conducted to determine the existing soil profiles and its bearing capacity meanwhile soil classification test have been carried out in the laboratory in order to obtain the soil properties. Generally, the existing ground soil consists of yellowish brown sandy clay with little gravel. The average of in-situ California Bearing Ratio (CBR) test base on BS1377 for the soil stabilised sections are ranges of 8 – 20% when tested using Dynamic Cone Penetrometer (DCP).

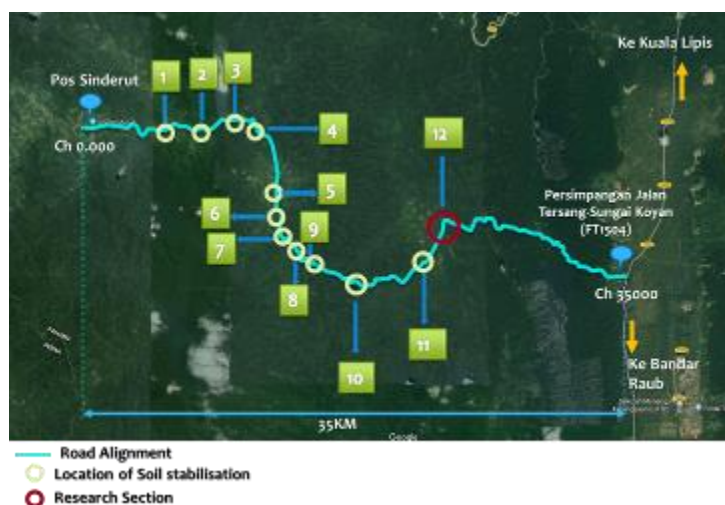


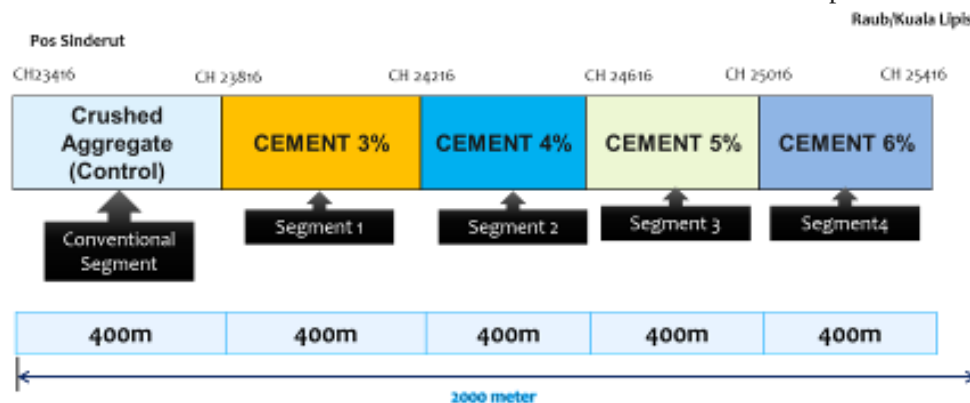
Figure 3. Location of soil stabilisation and research section.

Table 1. Location of soil stabilisation section.

Section	Start CH	Finish CH	Length (m)
1	5875	6285	410
2	6650	7850	1200
3	8650	8950	300
4	9651	9951	300
5	11950	12350	400
6	13170	13904	734
7	14150	14950	800
8	15350	15550	200
9	16744	17044	300
10	19419	20127	708
11	21724	23074	1350
12	23816 (research section)	25416	1600

The research section (Section 12) was divided into four (4) segment which is each segment was stabilised with a different percentage of the stabiliser. Initially, there are four (4) types of soil stabiliser was selected to be incorporated with an existing soil material on site for this study. The soil stabiliser namely portland cement, bitumen emulsion, hydrated lime and cement/fly ash blended were initially selected as the soil stabiliser to be used in this project. From the test report and analysis, it was found that the used of bitumen emulsion and lime was not suitable with the existing soil and it does not shows any significant improvement on the strength of the soil.

The mix design report also showed that the used of four percent (4.0%) of cement as soil stabiliser was achieved the minimum requirement of the strength of the stabilised layer. With that, 4% cement was applied on the selected of 11 sections except for research section. For study purposes, the research section at Section 12 was divided into four segments which is each segment are applying 3%, 4%, 5% and 6% of cement as showed in Figure 4 to identify how the soil stabilised perform in actual field when the content of the cement content was insufficient or more than the optimum content.

**Figure 4.** Segmentation of soil stabilization research section.

3. Structural design

The pavement structure was designed according to Arahan Teknik Jalan 5/85 (Pindaan 2013) and Design Guide for Alternative Pavement Structure Low Volume Roads [6],[7]. The pavement was designed base on the requirement of local traffic necessity which is in the range of low traffic volume. There are two types of structural designs which are conventional design using crusher run as road base material and stabilised an existing subgrade soil to became road base as showed in Figure 5 and 6 below. Both surface structures were paved using double-surface dressing layer.

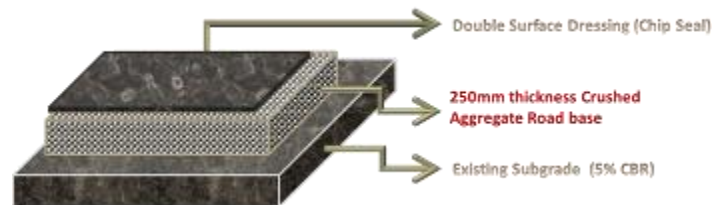


Figure 5. Conventional structure design.

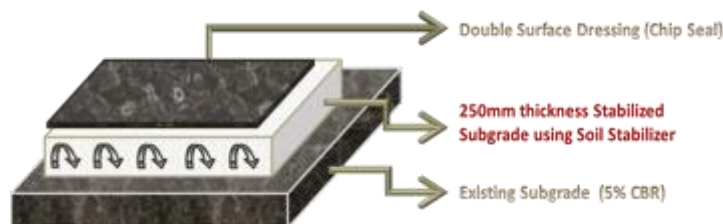


Figure 6. Soil stabilisation structure design.

4. Construction

The construction of soil stabilisation project using cement as the stabilising agent for this project was successfully completed by early 2016. The construction of soil stabilisation section started from site preparation to ensure that the soil surface is free from any foreign material such as grass, sticks, and rubbish. The prepared stretch should be compacted and free from boulders rocks or any other hard material to the designed depth and accessible by the stabilisation machinery. The stabilisation work was including spreading of the binding agent, mixing, compacting, shaping, testing and curing. Supply of cement in bulk or bags will be transferred into the purposed built spreader. After stabilisation areas have been prepared, the required quantity of cement was spread over the area. To achieve uniform spreading in line with the mixing requirement, the cement was spread in areas using a mechanical spreader. During the mixing process, the stabiliser machine was used to mix the existing soil materials with cement and water to the design thickness. The purpose of this mixing pass, however, is to incorporate moisture so that the required chemical reaction can take place so that even strength gain is achieved. The optimum moisture content was achieved by a connected water truck with the stabiliser machine.

After the mixing process, the motor graded was used to grade and form the desired cross fall as well as achieving finished surface levels. Finally, the vibratory compactor was used to compact the stabilised layer to achieve the desired density. The stabilised layer need to be cured before it was paved with double surface dressing.

The application of surface dressing started with spraying the polymer modified emulsion on the stabilised layer surfacing and then the single size of stone chipping precoated with adhesion agent was spreading through the road surface in two layers. The construction process was showed in Figure 7 below.



Figure 7. Soil stabilisation process.

5. Testing

5.1. Soil parameter

Laboratory and field testing was carried out before and after construction. Laboratory testing consisted of material testing to identify the characteristic of the soil and mix design to identify the suitable type stabiliser, the content of stabiliser agent and the optimum moisture content. The parameter of the soil materials was showed in the Table 2 below.

Table 2. Result of soil testing.

Soil parameter	Average
California Bearing Ratio (CBR), %	16
Plastic Limit	39
Plastic Index	33
Optimum Moisture Content (OMC), %	20
Maximum Dry Density	1.672
Passing 0.075mm sieve size	64%
Soil type	Yellowish brown sandy clay with little gravel

5.2. Mix Design

Initially, it was suggested to apply several types of conventional soil stabilizer namely cement, lime, and bitumen emulsion. Referring to the guide of selection of the stabilising agent for various plastic index value and content of fine. Figure 8 it showed that the soil material was usually suitable to be stabilized using lime.

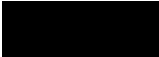
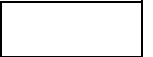
Plasticity Index	MORE THAN 25% PASSING 75 μ m			LESS THAN 25% PASSING 75 μ m		
	PI < 10	10 < PI < 20	PI < 20	PI $\leq$ 6 PI x % passing 75 μ $\leq$ 60	PI $\leq$ 10	PI > 10
Cement and Cementitious blends						
Lime						
Bitumen						
Bitumen/cement blends						
Granular						
Miscellaneous Chemical						
Legend						
Usually Suitable  Usually not Suitable  Doubtful 						

Figure 8. A guide to the selection of the stabilising agent for various PI values and content of fines [5].

However, the result from the initial mix design test showed that the existing soil material on site was compatible stabilised using cement compared to lime and bitumen emulsion. The second stage mix design process was carried out using Ordinary Portland Cement to identify the optimum cement content, optimum moisture content and maximum dry density of the soil stabilised mixture.

The result of the mix design was showed in Figure 9 and 10 below. The mix design samples were tested for Unconfined Compressive Strength (UCS) and California Bearing Ratio test in the laboratory. Sample 1, Sample 2 and Sample 3 were represented the different locations of the sample taken from the construction site. An existing material from the site was stabilised with 4%, 6% and 8% by mass of Ordinary Portland Cement. The Unconfined Compressive Strength (UCS) was carried out after cube molds cured for 7 days according to B.S. 1881. California Bearing Ratio (CBR) according to ASTM D 1883-07 test procedure also was carried out to identify the optimum stabiliser content in the mix.

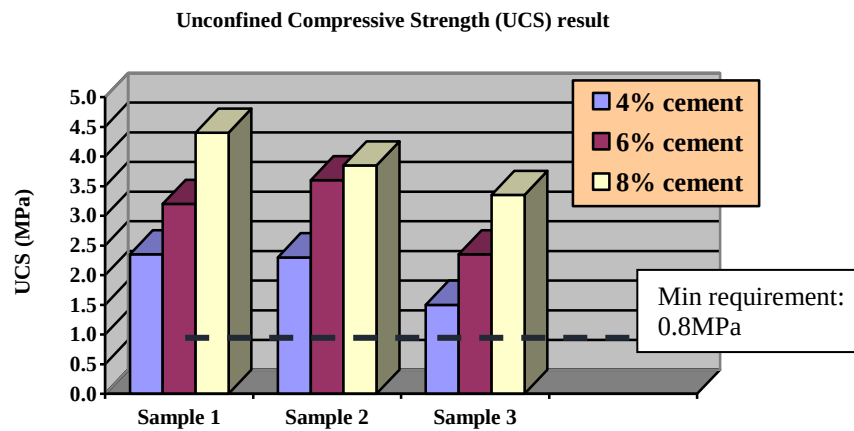


Figure 9. Unconfined Compressive Strength (UCS) result.

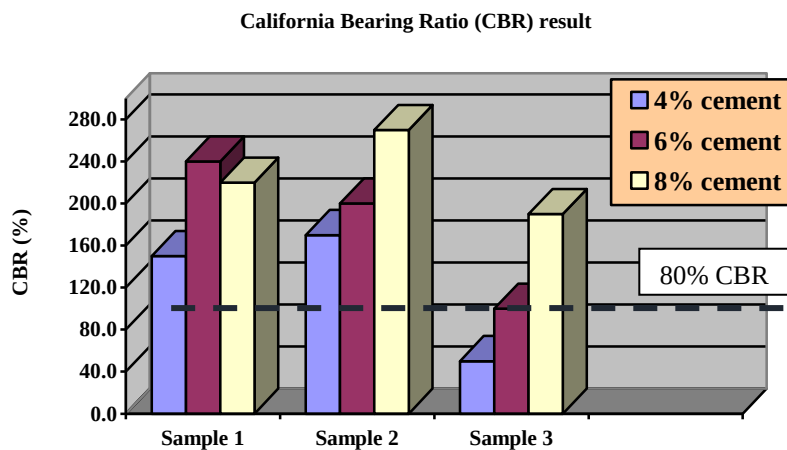


Figure 10. California Bearing Ratio test result (CBR).

From the report, it showed that most of the samples were complied with the minimum requirement of UCS and CBR values as stated in the specification which is respectively 0.8MPa and 80%. All CBR result comply with the specification except for sample 3 at 4% cement that suspected due to handling error since the property description and proctor results are consistent with other samples. It was concluded that all the test for the mix design was achieved the minimum requirement of soil stabilised strength at 4% cement content. Therefore, 4% of cement content by dry mass was applied for soil stabilisation project at the project site.

6. Result & analysis

Field testing was carried out to identify the performance of the stabilised pavement structure before and after construction. The performance of soil stabilised pavement structure was monitored before and after construction by conducting the field testing apparatus using Clegg Hammer and Lightweight Deflectometer.

The result in Figure 11 and 12 obviously showed that the used of cement increase the CBR value and the modulus of the existing subgrade material. The value of subgrade CBR was increased up to 400% after one month stabilised while the E-Modulus was increasing up to 200% after one month.

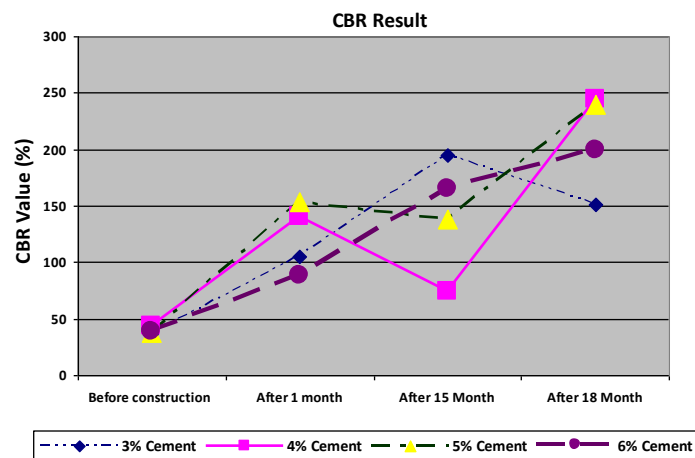


Figure 11. California Bearing Ratio test result (CBR).

From the result showed in Figure 11, the value of Subgrade was increased for all section after 15 months stabilised except for the section of 4% and 5% cement. This is maybe the effect of the slope failure that occurred during this due to high water table along with this section but the value of CBR was still above the value of CBR after 1-month construction.

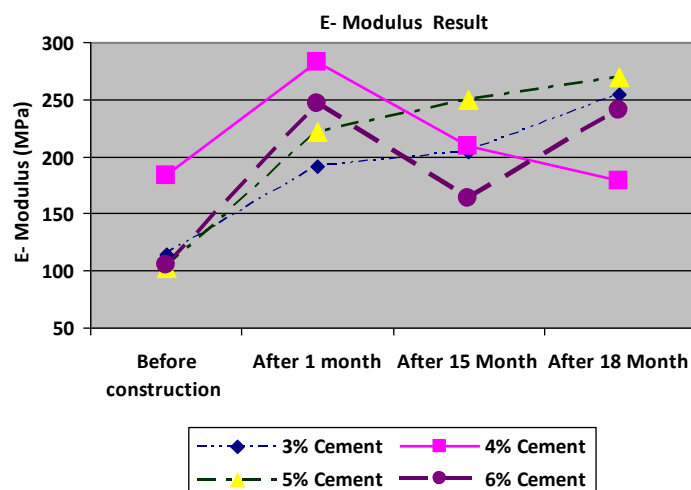


Figure 12. E-Modulus Result.

Field testing at Control Section was carried out after 12-month construction and it was showed that the Modulus value was 162MPa when tested using Lightweight Deflectometer. This result showed the increasing of Modulus value which is about 120% compared to the Modulus value of subgrade before construction.

From the surface condition survey that had been carried out randomly at site, it was showed that the most of area of the stabilised section still in good condition compared to the conventional section. Figure 13 showed the condition of the site at the stabilised section and conventional section after 18-month construction. The pavement was overlying with double surface dressing as the final surfacing throughout the length. Figure 13 showed that the surface materials of both sections peeled off and exposed the lower layer. This is may be due to the poor construction quality and quality control during construction of surface dressing itself. Therefore, the road surface which is consisted of the unbound layer was exposed to the water penetration became breakable to the high surface loading.



Figure 13. The condition at the site after 18 months.

7. Conclusion

Based on the findings, result, analysis, observation of the implementation of soil stabilisation technique in this project, it can be concluded as followed:

- i. To ensure that a uniform and the homogenous stabilised mix was achieved, it very important that the suitable machine became necessary but the condition of the remote construction site area may cause the difficulty on bringing the machine inside. It was suggested to allow the use of any simple machine or purpose-built machine as long as it can provide the homogenous stabilised mixture.
- ii. The mix design of for soil stabilisation should be always to be carried out at every project due to the difference of soil properties required different types and content of stabiliser agent.
- iii. Soil stabilisation using cement increase the existing subgrade after construction complete and performed well compared to the conventional method.

- iv. It was suggested to have a particular Malaysian design manual and specification in soil stabilisation to assist the engineer and construction industry to have a better design and quality control regarding soil stabilisation.
- v. The implementation of soil stabilisation technique should be extended to the higher hierarchy standard of the road such as federal or state road.

8. References

- [1] Cawangan Senggara Fasiliti Jalan 2016 *Buku statistik jalan edisi 2016* (Kuala Lumpur: Jabatan Kerja Raya).
- [2] Little D N and Nair S 2009 *Recommended practice for stabilization of subgrade soils and base materials - Final task report for NCHRP project 20-07* (Texas: National Cooperative Highway Research Program, Transport Research Board of the National Academies Texas Transport Institute, Texas A&M University College Station).
- [3] Garber N J and Hoel L A 2001 *Traffic and highway engineering third edition* (United State of America: University of Virginia).
- [4] Maureen A K 2009 *Stabilization selection guide for aggregate and native surface low volume roads* (U.S Department of Agriculture: National Technology & Development Program)
- [5] REAM 2010 *Manual on cold in place recycling - Workshop 1* (Kuala Lumpur: Road Engineering Association of Malaysia)
- [6] JKR 2013 *Manual for the structural design of flexible pavement ATJ 5/85 (Pindaan 2013)* (Kuala Lumpur: Jabatan Kerja Raya Malaysia)
- [7] Cawangan Kejuruteraan Jalan dan Geoteknik 2012 *Design guide for alternative pavement structures low volume roads*. (Kuala Lumpur: Jabatan Kerja Raya).