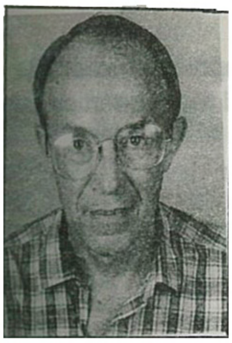

CASE STUDIES IN SOIL STABILISATION FROM AFRICA & CENTRAL AMERICA

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RINGKASAN

Seiring dengan pesatnya pertumbuhan industri di Indonesia maka kebutuhan bahan galian golongan-C semakin meningkat dari tahun ke tahun, kebutuhan material dengan mutu baik juga sudah menjadi suatu tuntutan, khususnya dalam pembangunan jalan dan gedung. Untuk memenuhi sekaligus menjamin selalu tersedianya bahan dengan mutu yang baik serta mengurangi kerusakan lingkungan yang ditimbulkannya, maka disarankan digunakan beberapa alternatif metode konstruksi jalan dan kalau memungkinkan lebih banyak memanfaatkan bahan/material lokal. Ini akan lebih menguntungkan secara ekonomi dimana biaya konstruksi diharapkan bisa ditekan atau dikurangi. Dua contoh hasil percobaan stabilisasi tanah diuraikan dalam makalah ini yaitu suatu percobaan stabilisasi yang berhasil baik sedangkan yang lain tidak agar dapat membandingkan teknik stabilisasi yang mana lebih menguntungkan dibanding teknik yang lain., dan penggunaan suatu metode konstruksi/teknik yang satu lebih baik dan memberikan manfaat dibanding teknik yang lain.

SUMMARY

The demand for aggregates increases year by year owing to the industrial growth in Indonesia and the necessity for more and better quality roads and buildings. To conserve good quality materials and to minimise environmental disruption it is always advisable to use alternative methods of construction and make more use of materials of marginal quality where possible. This can also have economic advantages in that construction costs can be reduced. Two examples of soil stabilisation, one successful the other not successful, are described in order to highlight the benefits and disbenefits of the technique

I. BACKGROUND

Chemical stabilisation, using lime or cement, is common in Indonesia especially in areas where local supplies of rock aggregates are not available. For example, many of the national and provincial roads in Eastern Sumatra, in the provinces of South Sumatra, Jambi and Riau, consist of lateritic soil stabilised with cement. Also in southern and west Kalimantan and southern West Irian there are examples of stabilised materials and possibly great future potential. However, information on the laboratory work preceding the selection of stabiliser, properties of the materials and, most importantly, the scientific evaluation of the performance of the roads after construction is difficult to obtain. It would merit a review but that is not the purpose of this paper. This paper will discuss two case histories from abroad, one from Belize in Central America and the other from Botswana in southern Africa where soil stabilisation has been used to construct roads. One was successful and the other was not successful. Both will be described and the reasons for success and failure will be explained. Both case histories were examples of collaboration between the Transport Research Laboratory (TRL) of the United Kingdom, the respective Public Works Departments of the countries concerned and the contractors responsible for construction of the roads.

II. REASONS FOR STABILISATION

Both materials were, in their natural state, of sub-standard quality, that is they did not meet the basic criteria of grading, plasticity and particle or mass strength required by the existing standards. But they were abundant in the area so using them for construction would give significant cost savings compared to transporting standard materials over great distances. Also, the traffic was low (defined as less than 400 vehicles per day, TRL Overseas Road Note), so it was assumed that normal standards could be relaxed without prejudicing road performance. It should be said here that this paper concerns the use of marginal materials in unbound roadbases. Normally one would not contemplate the use of marginal materials in asphalt construction because, weight for weight, the cost of the bitumen far outweighs the cost of the aggregate. For asphalt it is necessary to use clean, hard and durable stone.

III. TECHNIQUES OF EVALUATION

When considering the use of materials of sub-standard quality a sequence of steps must be followed.

1. The distribution of the materials must be assessed. They must be of widespread distribution, easy to obtain and easy to use. This is sometimes difficult to assess because natural materials, as compared to processed materials, are often very variable in composition.
2. Their engineering properties must be carefully determined. Sometimes it is advisable to determine their mineralogical and structural (that is fabric) properties also, for better understanding why they behave like they do.
3. The materials must be tested in full scale, trafficked road trials. There is often a significant difference between laboratory results and field results, as will be shown later.
4. Guidelines can then be proposed for their general use.

IV. RESULTS FROM BELIZE

4.1 Material Properties

The material was a soft limestone, of widespread occurrence in the north of the country, easy to dig and close to the existing road network. By comparison, stone supplies were quite distant. Its composition was quite variable but typically it had the properties listed in Table 1.

Table 1

Property	Soft limestone	TRL ORN31, 1993
% material passing 0.425 mm sieve	60	max 30
Plasticity Index	6	max 6
Plasticity Modulus	360	
Soaked CBR at BS Heavy Compaction (BS 1377, Part 4)	50	Min 80

Plasticity Modulus = Plasticity Index X %tage material passing 0.425mm sieve

The soft limestone was thus too fine in grading and too low in soaked CBR. Roads constructed elsewhere in the country using the soft limestone without adequate embankments had failed for this reason.

Although the fines content was high the plasticity was low. The reason for this was the high calcium carbonate content of the material, with a $CaCO_3$ content of 97%. The fines were thus not clay but calcite minerals which are not plastic.

As the plasticity index was low it was decided to stabilise the material with cement. Results of laboratory testing with 5% cement are shown in Table 2.

Table 2

Compaction % BS Heavy	UCS, M Pa		TRL ORN 31 UCS, 28 DAYS, MPa
	7 DAYS	28 DAYS	
92	2.5	4.0	3 to 6
97	2.8	5.0	(CBM 1)

UCS = Unconfined Compressive Strength, M Pascals.

CBM 1 = Cement Bound Material, Class 1 (from TRL Overseas Road Note 1, 1993)

The laboratory results indicated that the performance of the soft limestone would be excellent with 5% cement.

4. 2. Field Trial

The experimental section, 107m (300 feet) long, formed an integral part of a new road, 45km roadbase and double surface dressing. Predicted traffic was 0.5 million equivalent standard axles (esa) for a 10 years design life.

The experimental section was situated in an area of swampy ground that was seasonally flooded. Approximately 650mm of fill was placed to raise the road above the anticipated maximum flood level. Then 100mm of untreated soft limestone subbase was placed and compacted to 95% of BS Heavy Compaction.

The soft limestone roadbose was spread and 50kg cement bags laid every 3.45m^2, equivalent to 5% by weight of the 150mm compacted thickness. The bags were opened and the cement spread by rakes then mixed with the soft limestone using a grader. Water was then added and the material mixed again before compaction with smooth wheel roller for 2 hours. An average 94% of BS Heavy Compaction was obtained. A prime coat of MC 3000 was applied at 0.7 l/m to assist curing. The next day the first layer of surface dressing was applied. The final surface dressing layer was applied three months later.

4. 3. Performance

Performance of the section has been excellent. In Table 3 the ruts and deflections are shown when measured in 1992, for the control (crushed stone roadbase) and stabilised section. This was 14 years since construction during which time the surface dressing was renewed once. Traffic was estimated at 750,000 esa.Vehicles per day average 700, not low traffic according to the definition quoted earlier.

Table 3

Section	Ruts, mm	Deflection, mm x 10^{-2}
Control	5 to 10	50 to 80
Stabilised	6 to 8	15 to 25

Virtually no cracking was observed in the stabilised section. This can cause problems on some cement-stabilised roads and is caused by natural shrinkage of the cement component. If the roadbase is overlaid by a thick asphalt layer the cracking can be reflected through it and eventually cause potholing. When high cement contents are used the susceptibilty to cracking is increased. Surface dressing, being comparatively more bitumen-rich than typical asphalt, is more flexible.

Values of 9 M Pa were obtained from samples collected from the road at this time, showing an appreciable gain in strength compared to the laboratory results.

4.4 Conclusions

The use of the soft limestone stabilised with cement has been a success. In future it may be possible to use lower quality, that is more plastic, soft limestones for stabilisation. The material performed even better than the standard construction using crushed stone. An additional benefit is the cost saving. It is estimated that by using cement stabilisation $18,000 per km construction cost could be saved. It was not necessary to quarry, crush and transport the stone. For the 45km road this would have resulted in a total saving of about $750,000.

V. RESULTS FROM BOTSWANA

5.1 Material Properties

Most of Botswana is desert (the Kalahari) with extensive deposits of fine sand (>95% passing 0.425mm sieve). The sand covers 80% of the area of the country. The sand is of uniform size and occasionally is impregnated with calcareous material, resulting in gravelly materials known locally as calcretes. The amount of calcareous material is very variable resulting in a wide range of engineering properties but the more calcareous and harder calcretes can be used for road construction. However, it was useful to determine if the lower quality, less calcareous calcretes, which are widespread, could be improved by stabilisation so that they could be used for road construction. Their typical properties are shown in Table 4.

Table 4

	Low quality calcrete	TRL ORN 31
%tage passing 0.425 mm sieve	80	max 30
Plasticity Index	15	max 6
Plasticity Modulus	1200	max 90
Soaked CBR at BS Heavy (BS 1377, Part 4)	40	min 80

The low quality calcrete thus had a low strength (CBR), and too fine and too uniform a grading. Also it was too plastic.

It was decided to carry out separate laboratory tests to stabilise the calcrete with hydrated lime ($CaOH_2$) and cement. The strength gain results are shown in Table 5, using 3% of the hydrated lime and cement, at 100% BS Heavy Compaction.

Table 5

Section	7 days CBR, %	28 days CBR, %
Calcrete + 3% lime	80	150
Calcrete + 3% cement	120	160

As a result of these results it was decided to proceed with the construction of a full scale trial with the stabilised calcretes as roadbases.

5.2 Field Trial

Construction of the full scale trial took place in 1979 and formed part of a contract to extend the national road network, although initially the road was built to serve the needs for a new diamond mine. Altogether eleven trial sections were built by the contractor under TRL supervision, each section 100m in length. Two sections were controls, using crushed rock roadbases and the remaining nine sections were calcretes of various qualities. A sketch of the trial is shown in Fig 1. One of the nine sections was cement stabilised low quality calcrete (Section 4) and the other was lime stabilised (Section 5). The roadbases were 150mm thick and constructed on a sand subbase and compacted sand embankment raised about 0.5m above the surrounding land. Predicted traffic was estimated at 30,000 esa per year, most in heavy trucks carrying supplies to the mine.

The cement and lime stabilised sections were constructed in a similar manner to the Belize trial but the mixing operation took over three hours to complete. Compaction immediately followed and a prime coat of MC30 (less viscous than the MC 3000 used in the Belize trial) applied within 24 hours. Compacted densities and thicknesses of the two sections are given in Table 6.

Table 6

Section	Density, % of BS Heavy	Thickness of roadbase, mm
Calcrete + 3% lime	97,4	167
Calcrete + 3% cement	97,2	156

A double surface dressing was applied four months later.

5.3 Performance

Fig 2 shows the development of CBR in the stabilised sections after construction. It is clear that no gain in strength occurred and thus stabilisation did not happen. Probably the sections dried out in the hot, arid climate despite being covered with prime immediately following construction. Fig 3 shows that this almost certainly happened and that, therefore, curing was not effective. With hindsight it would have been better either to have used a more viscous prime coat or to have surface dressed the trial sections as soon as possible after construction and not four months later.

However, for various reasons, it was not possible for the contractor to do this.

Because the stabilisation was not effective the subsequent performance was poor, as indicated from the rut depth and deflection data shown in Table 7, after six years' traffic, or 150,000 esa. Traffic was about 250 vehicles per day.

Table 7

Section	Ruts, mm	Deflection, mm x 10^{-2}
Control	5	20
Calcrete + 3% lime	15	60
Calcrete + 3% cement	10	55

Unfortunately, there was no opportunity to reconstruct the stabilised sections so the feasibility of stabilisation remains unresolved. Curiously, the unstabilised low quality calcrete sections performed far better than the stabilised sections. The reason for this is still not known.

In 1994, owing to the poor condition of some of the trial sections, the whole experiment was reconstructed with standard materials. By this time the most heavily trafficked lane had carried 0.5M esa. The lower quality (unstabilised) calcretes had performed acceptably to 0.3M esa, about 10 years. The higher quality calcretes were still in an acceptable condition at the time of reconstruction.

5. 4 Conclusions

Stabilisation was not successful in this field trial owing to ineffective curing of the calcretes.. It still remains unproven whether it is an effective technique in hot, dry climates and, to this day, the writer is not aware of any other example in Botswana where stabilisation has been attempted. The main problem is in achieving proper curing in these conditions.

VI. DISCUSSION

What have we learned from these trials ?

Firstly, chemical stabilisation can be a very effective technique, both in technical and financial terms. However, it is a technique requiring careful investigation first by laboratory investigation and secondly with a field trial.

Secondly, the field trials must be full scale and include traffic. This is the only way that the engineer can be certain of the feasibility of the technique. Laboratory tests tend to overestimate the quality of the raw materials. A successful full scale trial requires close collaboration between researcher, contractor and client. This may be difficult because each may have a conflicting programme. The researcher must be involved in all phases of the trial.

Thirdly, the following factors are important for soil stabilisation:

- soil properties
- stabiliser quality
- stabiliser content
- uniformity of mixing
- compaction
- correct moisture of the mix
- start of and duration of curing
- method of curing

The margin for error is small and lack of proper control can lead to failure.

It is hoped that the foregoing has given a good illustration of these techniques.

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