PAVING PREPARATION FOR INDUSTRIAL SITES: A CASE STUDY FOR TESTING PROCEDURES

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SHORT SUMMARY

The importance of in-situ and laboratory testing in sub-surface assessment and preparation prior to lime-stabilisation is described with reference to a Palmerston North case study.

Emphasis is given to the problems that can arise from deficiencies in sub-surface material characteristics and the importance of credible test personnel and procedures.

INTRODUCTION

The Palmerston North City Council has been involved in the business of lime and cement stabilisation for about 9 years but our major interest was forced on us 6 years ago when the Manawatu catchment board severely restricted the extraction of river run for the production of reading aggregates from the Manawatu river. Essentially the only metal now removed from the river course is for concrete and road sealing chip production.

Thus local authorities in the region have had to turn to lime or cement stabilisation in road construction. The Palmerston North City Council now has a system of removing the metal layers, stock piling them, and then treating the subgrade clays with lime or cement, and replacing existing metal layers and then topping up with some AP 40 to finished levels.

BACKGROUND

An area of 80 mm red interlocking concrete block paving, comprising blocks and bedding and joint sand, was laid by a local blocklayer onto a base prepared by a local reading engineering contractor. It is believed the "investigation and design" of the lower pavement layers was left to the contractor because of his previous extensive experience in road construction. He was supplied with a copy of NZS.3116:1981 by the client and it is believed he was required to "prepare the lower pavement layers to a standard suitable for the laying of concrete block paving".

Some clay was removed from the area and river run base course used to fill.

The blocks were laid on a natural sand although the exact depth of sand used is unclear. Upon completion of the block laying (which followed traditional recommended practice) a pneumatic wheeled roller made up to six passes over the pavement to further compact the system, ^oiling was stopped prematurely in one area due to the wave action occurring.

The area was then opened up to traffic, with heavy trucks passing frequently. The pavement appeared to be performing satisfactorily initially but the passage of trucks appeared to initiate a loss of block to block interlock with each unit able to be rocked.

There was known to have been heavy rainfall during construction of the lower pavement layers and during the laying of the blocks themselves. In both cases work ceased for a period before restart. The water table over the site was also high during the construction period and pumping was required to remove some unwanted water. The paving slab movements indicated sub-surface problems and the NZ Concrete Research Association became involved. I am indebted to D P Page of this organisation for the above background.

FIELD TESTING

Site Preparation

The areas to be tested are marked out where test holes are to be excavated. This is usually at 50 metre spacings. This is a minimum requirement in our experience since we have been previously caught out with 100 metre spacings, where test material taken proved not to be representative enough of the actual material excavated when construction commenced.

FIGURE 1: SOIL TYPES - PALMERSTON NORTH CITY



MATERIAL TYPES	CBRS	DENSITY CORRECTION	MOISTURE %	LIME % USED
1. Heavy Brown Clay	10 to 15	-20/with lime -38	25%	4%
2. Old Swamp Area	5 to 10	-31/with lime -55	36%	3% to 4%
3. Pit Metal	20 to 50	-15/with lime -20	8%	2%
4. Grey Clay	3 to 10	-40/with lime -50	37%	3.5 to 4.5%
5. Grey Clay + Sand	1 to 5	-7/with cement -10	15%	5 % plus Cement
6. Sandy Silts	1 to 8	+ 10/with cement +10	3%	1.5 + 1.5 Cement
7. Clays + Volcanic Ash	3 to 5	-25/with lime -30	30 to 55	3% to 4%

SCALA PENETROMETER TEST

A 9 kg weight is dropped a set distance to drive a penetrating cone at the end of a steel rod into the ground. The number of blows per 75 mm penetration are recorded and used to work out bearing pressure in kPa. The test is described in NZS 4402 (1986) Test 6.5.2. Test results from Firths Yard 29.6.87 were as shown in Table 1.

		TEST HOLE 1	TEST HOLE 2
Penetrometer tests from a starting depth of 525 mm below paved	First 450 mm	CBR. 2.2 kPa 34.0	CBR. 2.2 kPa 34.0
	Over 1150 mm	CBR. 16.0 kPa 184.0	CBR. 18.0 kPal96.0

TABLE 1: SCALA PENETROMETER TEST RESULTS

CROSS SECTION LAYERS

The depth of each recognisable layer is measured and noted down for future reference. Clay layers afire recognised by colour and texture (and even smell in a fresh excavation) and are used to complete a comprehensive soil/clay map of the city. The depth of each layer is also used to indicate the extent of different strata over the city area. Samples of each layer are placed into a sealed container for subsequent moisture content testing. A "generalised" soil/clay profile for Palmerston North is shown in Figure 1. Firths Yard runs from grid B7 to grid B6 and its determined moisture of 25 % agrees with the map profile. Its depth profile, from bore logs, is as follows in Table 2.

TEST HOLE 1	TEST HOLE 2
Sand 50 mm	Sand 50 mm
Top Course 85 mm	Top Course 85 mm
River Run 390 mm	River Run 390 mm
Clay 150 mm	Clay 160 mm

TABLE 2: CROSS SECTION RESULTS

CBR Testing

This test is described fully in NZS 4402 (1986): Test 6.1, and gives an evaluation of the bearing capacity of soil.

A CBR mould with a cutting edge is placed onto the base of the test hole after all other tests have been completed. The digger driver then pushes the mould into the clay with the lease disturbance possible until the top of the mould is flush with the hole floor. It is then carefully removed, both ends trimmed smooth, and placed in a numbered plastic bag.

Test moulds taken in the field are weighted so that bulk density can be determined and moisture contents are obtained. The mould is then CBR tested to NZS 4402, part 6 (1986) test 6.1.2. If engineering staff have by this stage got some idea of metal depth they propose using on top of the stabilised layer, the laboratory staff can use calculated surcharged weights when the CBR test is performed.

This test should provide a confirmation of CBR results obtained by Scala Penetrometer.

Results for Firths Yard ranged from 6.0 to 6.7 as follows in Table 3.

TEST HOLE 1	
CBR test on mould obtained from clay layer	CBR 6.0
TEST HOLE 2	
CBR test on mould from clay layer	CBR 6.7

TABLE 3: CBR RESULTS

DENSITY FIELD TEST RESULTS

Layer	Thickness (mm)	Test depth below layer surface (mm)	Bulk density (kg/m^3)	Dry density (kg/m^3)	Moisture content (%)
Sand	50		2144	1952	9.8
Top Course	85		2101	1950	7.7
		100		8.3	
River Run	390	150	2334	2151	8.5
		200	2346	2151	9.0
		250	2320	2142	8.3

TABLE 4: TEST HOLE 1 - Results of density testing using Troxler surface moisture-density gauge Model 3411B (Test date 29.6.87)

Material	CBR	Bulk Density	Dry Density	% Moisture
Untreated clay	6	1.92	1.59	26.5
2 % added lime	22	1.89	1.56	24.7
4% added lime	35	1.86	1.53	21.3
6% added lime	60	1.88	1.56	20.2

TABLE 6: Lime stabilisation tests on underlying clay material

LIME	UCT MAX DIAL GAUGE READING	FAILURE LOAD kN	UNCONFINED STRENGTH	UCS RATIO	SLAKING TIME
Nil	100.0	2.63	0.38MPa	-	7 hrs
2%	150.0	3.91	0.48	1.26	Slight at 57 hrs
4%	245.0	6.34	0.78	2.05	Nil at 57 hrs
6%	282.0	7.29	0.90	2.37	Nil at 57 hrs

TABLE 7: SLAKING TESTS FIRTHS YARD

With the addition of *3%* lime, a CBR of 30 can be reached and this would have been a sufficiently firm base to work from. This would also have allowed a reduction in necessary excavation from 390mm to, perhaps, 200mm as a sufficient base for the paving slabs.

Lime stabilisation also waterproofs the clay and thus prevents later water movement through the stabilised layer as, say, a surrounding water table rises.

LIME STABILISATION

It is obviously easy to comment on problems with the wisdom of hindsight. High rainfalls and a high water table stacked the odds against the contractor. The contracting job was well done and all procedures seemed to follow New Zealand Standards for the laying of paving materials. Indeed, had the job been started in earlier drier months with the usual low water table, it is probable that no problems may have eventuated.

LABORATORY TESTING

Saturated CBR

After the CBR test above, the plunger hole is filled, a base plate placed on the end and the mould placed in a water bath for 4 days for a saturated CBR test after that time. This should indicate a site CBR under the worst winter or high water table conditions, and the possible swelling properties of the clay or soil. The saturated CBR for Firths Yard was 2.0 to 2.5.

pH Testing

This test is done on all samples collected regardless of apparent similarity since pH differences need not show visually. Acid pHs are not uncommon in Palmerston North because old acidic lagoon beds frequently occur. Most city clays range from 6.5 to 7.5 in pH but values in such beds as above can be as low as 5.5. The test is described in NZS 4402, part 1, (1986).

Moisture content

An amount of at least 25 kg of base clay or material to be laboratory tested should have been taken and kept at its original moisture. The sealed samples thus taken in the field provide subsamples for moisture content testing as per NZS 4420, Part 2 (1986), Test 2.1.

Quick Response Test (RRU Technical Recommendations No. 2 Test 4.3.1.)

A straight clay sample of original moisture content is made up in a proctor mould. Our laboratory uses New Zealand "heavy compaction" achieved by three layers formed by 27 blows each. At this stage a bulk density reading is taken as shown in Table 6. The sample is extruded from the mould and placed in a plastic bag, the bag is placed in a plastic bucket and then put into a water bath at 40°C for 48 hours.

From past experience we select lime additions of 2%, *4%* and *6%* and test each mixture with the original clay in the same manner as the straight sample above.

Moisture contents of each mixture after mixing are separately determined at this stage. pH tests are also done and noted.

After 48 hours samples are removed from the water bath and taken out of their bags and placed on a bench to surface dry for about 10 minutes. At this stage they are ready for an unconfined compression test. This is done by placing the sample in the CBR machine and applying pressure until a maximum dial gauge reading is obtained. Results are shown in Table 7.

Slaking Tests

After the unconfined compression test, part of the mould sample is immersed in water in a beaker for several days or even weeks to ascertain the slaking time of each percentage of lime in the samples. Results for Firths Yard are given in Table 7. Note that we have retained an immersed sample of 4% lime-added clay from May 1987 that has remained unchanged since then.

Layer	Thickness (mm)	Test depth below layer surface (mm)	Bulk density (kg/m^3)	Dry density (kg/m^3)	Moisture content (%)
Sand	50		2013	1769	13.8
Top Course	85		2210	2023	9.2
		100	2257	2126	6.2
River Run	390	150	2316	2184	6.0
		200	2302	2170	6.1
		250	2279	2146	6.2

TABLE 5: TEST HOLE 2 - Results of density testing using Troxler surface moisture-density gauge Model 3411B (Test date 23.7.87)

DENSITY TESTING ON SITE

This should be undertaken while the job is in progress to ensure that the correct compaction has been achieved. The Palmerston North City Council has a nuclear density moisture meter at its disposal which can provide instant on-site compaction and moisture information as the job proceeds and can indicate any remixing or extra watering requirements that can be made immediately. An example of dry density test field testing is shown in Figure 2.

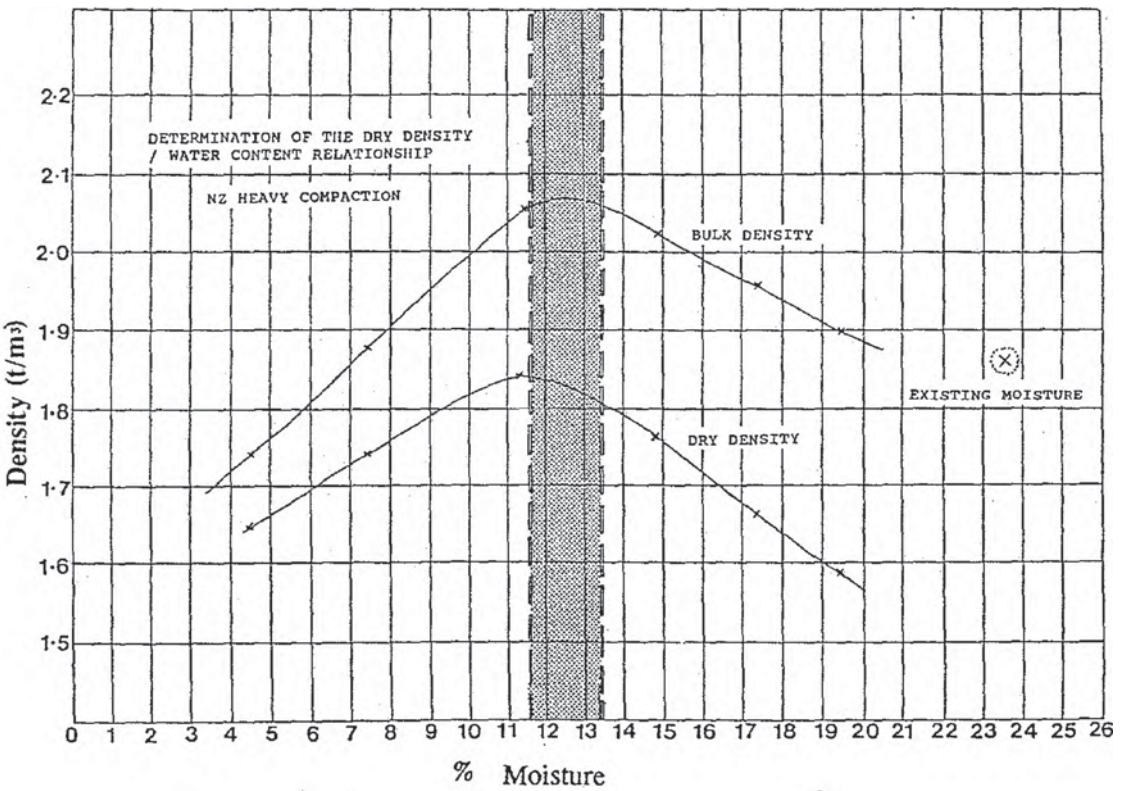

FIGURE 2: DENSITY/WATER COMPACTION CURVE FIRTHS YARD

Looking at the problem now from this privileged perspective it is suggested that lime stabilisation should have occurred first to get a firm base to place the river run and subsequent layers on to. It has subsequently been established that the underlying clay type can be readily stabilised. Test results are shown in Tables 6 and 7.

CONFIRMATORY TESTING

Within a week of the original samples being tested, the optimum lime mixture can then be mixed up and compacted into a CBR mould and tested to ascertain a likely CBR value resulting from lime stabilisation. In general, with a clay subsgrade CBR of 5, an improvement to a CBR of 25 - 35 can be expected with 4% lime. Similarly, the results that might be expected from rehoeing can be gauged by laboratory testing. Figure 3 shows CBR improvement after laboratory remixing and air-drying of a 3% lime mixture.

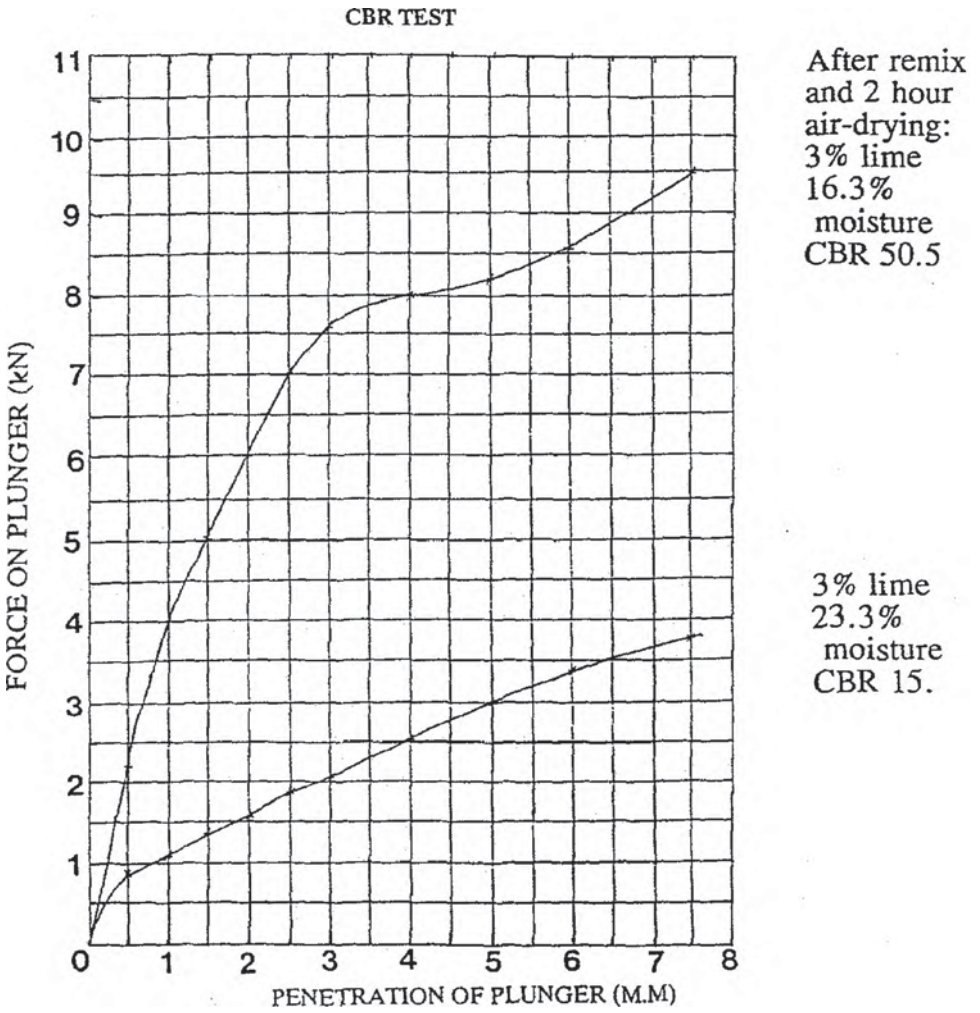

FIGURE 3: EFFECT OF REMIX AND AIR-DRYING
ON A LIME STABILISED MIX

THE ACTUAL REMEDIAL WORK

In December 1987, the following remedial programme began to correct the block pavement problems:

1. Subgrade Drainage

   - excavate trenches to 75mm below final drain invert level.
   - stockpile the excavated metal course for later use and remove any clay or clay contaminated material from site.
   - backfill with 75mm of compacted filter material and install subsoil drains at minimum 1 % grade.
   - backfill with filter material compacting in 150mm layers.
   - backfill at least the top 200mm of the trench with base course material from the stockpile and compact in two 100mm layers.
   - perform 8 passes along each trench with the wheel of a forklift carrying two full pallets of cobblestones.
   - (The filter material above to be 20/7 metal course with minimum crushing strength 100 kN or material complying with NRB F/2).

2. Base course preparation

   - scarify the top 20-40 mm of the total surface.
   - apply a blinding layer of NRB M/4-AP20 in varying thicknesses as necessary to redefine the contours as per contract drawings and compact thoroughly with the final base course contour levels being final site levels less 80mm.

3. Strip Drains

   - chain cut 150mm deep, 60mm wide trenches for strip drainage.

4. Block laying

   - relay Stockholm blocks as per NZS 3116.

CONCLUSIONS

It is hoped this paper illustrates 3 important features relating to paving base preparation for industrial sites.

1. The value of sub-base materials testing. Preferably this should be in anticipation of the job's requirements but the above also shows its use as a remedial diagnosis tool.
2. The potential of lime stabilisation to greatly enhance base preparation.
3. The problems of remedial action when the above are not considered.

Careful test sampling carried out by trained laboratory staff maximises the information that may be gained from each test site and increases credibility of subsequent laboratory testing. Most methods, equipment and accuracy of measurement are set down by established standards which must be followed carefully to ensure a desired quality outcome. Many civil engineering laboratories in New Zealand are now TELARC registered. While this does not guarantee their results (nor mean that non-TELARC laboratories are not capable of equally good results) this registration does indicate that a laboratory has had its personnel, expertise and test procedures audited, and some credibility in test performance should result. Remember however that laboratories are really only as goods as the technical staff doing the hands-on work and their particular experience.

Where at all possible, the SAME PERSON should collect the test hole samples, laboratory test them, and be the person in control on in-situ testing e;g. slaking lime, mixing, compaction and density measurements. Experience indicates this allows a smooth, problem-free construction job.

Reading construction is expensive and the costs are becoming increasingly subject to inspection, audit and review. This merely increases the importance and value of quality control testing, the costs of which are usually trivial in comparison to the labour and material costs of reading, or the costs of repair after failure.

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