Subgrade Moisture Conditions for Pavement Design of New Zealand Roads

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6. **Results** *(continued)*

Executive Summary

A research project was carried out in 2001-02 to investigate subgrade soil water conditions of road pavements in New Zealand, in particular the applicability of soaked or unsoaked test specimens, and seasonal influences on subgrade stiffness.

Three pavement test sections (Kohimarama Road, Blockhouse Bay Road and Bristol Street) from the Auckland region were selected for a two-year investigation to determine the appropriate moisture conditions and strength/stiffness properties of the subgrade for pavement design. Three test locations at each test section were established, and test pits were excavated in the left wheel track and at the carriageway centreline, four times during the monitoring period. Each test pit was logged and photographed as well as being tested for in situ CBR[1], dynamic cone penetrometer (DCP) and water content tests. Standpipes for water-table levels were installed in one test location at each site. In addition, soil samples were recovered for laboratory (soaked) CBR tests.

The test results showed very few clear relationships between the various parameters measured. No relationship was found between the monthly rainfall and the subgrade water content or the in situ CBR test results. In addition, the transverse location (across the carriageway) of the test pits had no influence on the results.

Monthly standpipe records showed that two of the three sites (Kohimarama Road and Blockhouse Bay Road) did not show ground-water level within 1.8 m of the pavement surface during the monitoring period. Ground water was within 1.8 m in the Bristol Road standpipe and a reasonable correlation was recorded between the ground-water level and the magnitude of the monthly rainfall.

A reasonable correlation was also found between the in situ subgrade CBR results and the corresponding values inferred from the DCP tests over the top 100 mm of subgrade. This verifies the applicability of the DCP to CBR relationship presented in the AUSTROADS (1992) *Design Manual*, at least for the conditions encountered at the test locations.

The laboratory CBR test results showed that soaked test conditions would be appropriate for the Blockhouse Bay Road and Bristol Street subgrades. However, soaked conditions would be overly conservative for the Kohimarama Road subgrade and would not give a true indication of subgrade strength. This appears to be reasonable given that Kohimarama Road is sited on a ridge and the ground-water level is most likely at a significant depth below the top of the subgrade.

A procedure for determining the appropriateness of soaked or unsoaked subgrade testing conditions has been developed in this research. It is intended for routine design situations where frequent and/or long-term subgrade monitoring is not justifiable. The proposed distinction between the applicability of soaked and unsoaked test conditions is based on the potential for the ground-water level to lie within 1 m of the top of the subgrade for any significant period of time or on a repeated basis during the pavement's life. This is dependent upon a number of issues such as topography, inundation potential, soil properties, drainage conditions, rainfall, etc. Other important factors are the water content and density conditions for preparation of the test specimens.

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[1] CBR California Bearing Ratio

Where the subgrade soil is to be placed, i.e. in a fill situation, the specimens should be prepared to the specified field water content and density.

In cut or at-grade situations the test specimens should be taken as undisturbed, or reconstituted to field conditions with due consideration of any seasonal effects.

The research was limited by the small number of test locations and relatively short monitoring period. Further research should be carried out to investigate the issues raised in greater detail, and over a longer time.

Abstract

A research project was carried out in 2001-02 to investigate subgrade soil water conditions of road pavements in New Zealand, in particular the applicability of soaked or unsoaked test specimens, and seasonal influences on subgrade stiffness.

Test sections were established on three roads in the Auckland region. The test sections were subjected to four rounds of field tests over a period of two years to determine subgrade water content and strength/stiffness properties. Standpipes were installed to measure ground-water levels and subgrade samples were taken for laboratory (soaked) CBR tests.

The results showed very few correlations between the various subgrade test parameters measured. No clear relationship was found between rainfall records and subgrade water content or in situ CBR. A reasonable correlation was found between the ground-water level and the rainfall record at one test site, and the in situ CBR and dynamic cone penetrometer-inferred CBR showed reasonable correlation.

The laboratory CBR tests show that soaked soil conditions would be appropriate for two of the sites but overly conservative for the third site. The observations are considered to be consistent with the topographical features of the various sites.

A simple method for determining the applicability of soaked or unsoaked parameters is presented, based on an assessment of the potential for the ground-water level to be within 1 m of the top of the subgrade. Factors that influence the ground-water level are discussed.

1. Introduction

1.1 Objective

The objective of this research project was to investigate the appropriate subgrade moisture conditions for mechanistic pavement design for New Zealand roads.

One of the main aims was to determine if the use of soaked subgrade parameters is appropriate for road pavement design in New Zealand. Soaked subgrade parameters have traditionally been used in this country, but this is a conservative approach which has been questioned. If unsoaked subgrade parameters can be used in appropriate circumstances, the procedure may allow thinner, and therefore more cost-effective, pavements to be designed.

The main tasks for the research were:

- reviewing the recent international technical literature on subgrade moisture issues, and
- carrying out a practical investigation comprising field and laboratory testing of three pavements in the Auckland area.

The test data were analysed in relation to meteorological records to determine any significant correlations.

1.2 Mechanistic Pavement Design

Most road controlling authorities around the world, including Transit New Zealand, use a mechanistic approach to pavement design. This follows the general procedure outlined here:

- A trial pavement structure is proposed, composed of a sequence of linear elastic layers.
- Elastic theory is used to determine critical strains under standard loading conditions.
- The critical strains are related to pavement life using 'performance criteria'.
- The pavement model is adjusted until the required life is achieved.

Each pavement layer is characterised in terms of two elastic parameters: elastic modulus (E) and Poisson's Ratio (ν). These parameters, especially elastic modulus, must be determined with appropriate accuracy and reliability so that the design model closely represents the in-service pavement. However, establishing the elastic parameters can be difficult because pavement materials are inherently variable from one point to the next (both horizontally and vertically), and their elastic moduli are influenced by a number of effects, some of which are within the designer's control, but many of which are not.

The variability of material properties can be addressed by using a statistical approach to the characterisation. In the analysis of highway pavements, this is generally achieved by assessing material parameters at a 10 percentile confidence level. This means that we would expect 90% of the materials to be superior to those used in the design. In simple terms, this is analogous to saying that at the end of the pavement's design life, only 10% of the pavement area should be in a 'failed' condition.

1.3 Significance of the Subgrade

The subgrade provides the ultimate support for the pavement and the imposed traffic loads. The level of support is dependent upon:

- soil type;
- material density; and
- moisture content, both during construction and in service.

Quantifying the level of support provided by the subgrade is the most important aspect of determining the pavement design thickness.

One important influence that the designer has at least partial control over is water in the pavement layers and the subgrade. It is well established that water can have significant detrimental effects on pavement performance, particularly in subgrades comprising plastic soils. Therefore, when characterising subgrade materials for pavement design, an appropriate moisture condition must be used for testing.

This is a complex issue, as several influences may contribute to the movement of water into, or out of, a pavement structure. A further complicating factor is that many pavement engineers cannot agree on some of the fundamental behaviour of moisture in pavements. The contradictory views are generally about the permeability characteristics of unbound base and sub-base layers.

Moisture behaviour affects not only subgrade soils but also the upper pavement layers, though permeability of upper layers also influences subgrade moisture conditions.

Chapters 2, 3 and 4 of this report present the results of a review of the recent technical literature on the following topics:

- moisture in pavements;
- the effect of moisture on subgrades; and
- subgrade characterisation for design.

Relevant literature abstracts were identified using the TRIS, ITRD and ROAD road engineering literature databases (held by ARRB in Australia). Further information has been obtained from private, academic and road controlling authority sources.

A Glossary of abbreviations and definitions of terms is appended.

2. Moisture in Pavements

2.1 General

The presence and variation of moisture is generally accepted to have a significant influence on the performance of a pavement structure. Moisture can affect the mechanical and volumetric properties of not only subgrade soils, but also the upper pavement layers.

The issue of moisture in pavements is very complex. It is, as stated in Section 1.3 of this report, a source of some disagreement among pavement engineers. For example, a common view is that one or more of the unbound pavement layers should have an open grading so that any water that enters the pavement can escape without developing high positive pore pressures. Cedergren (1974) states that water can percolate through pavement layers and drain freely at the road shoulders.

Another view is that the pavement layers should be as impermeable as possible so that water is not able to enter the pavement structure (Tonkin & Taylor 1979). Supporters of this concept may argue that drainage layers can allow water to enter the pavement structure rather than escape from it.

Adding to the complexity of the issue is the inherent variability of pavement construction materials, in particular of subgrade soils. Subgrade soils at any given site can vary in numerous properties, many of which can affect the way the soil behaves in the presence or variation of moisture.

2.2 Sources of Water

Water can be transferred into or through a pavement in three ways: entry, redistribution, or evaporation (Lay 1981).

Entry
Water enters the pavement structure by infiltration or seepage from higher ground, verges, shoulders, surface cracks, or permeable surfaces. Sources of water include rain, melting snow or ice, leaking pipes, ground water, or water used in construction or maintenance (NAASRA 1983).

Redistribution
Water is moved within the pavement materials as a result of positive or negative pore water pressures. Pressure changes may be caused by wheel loads or pore water tension effects.

Evaporation

Water in vapour form moves as a result of a temperature gradient in the pavement structure (Lay 1981).

2.3 Factors Influencing Moisture in Roads

Several factors can influence the moisture condition in a road pavement. Those that are beyond the control of the designer are:
- subgrade soil type, i.e. mineralogy, grain size and grading;
- climate;
- topography;
- water table depth;
- adjacent vegetation;
- adjacent irrigation;
- tendency to flood.

The influencing factors that are within the control of the designer (Tonkin & Taylor 1979) are:
- pavement cross-section geometry;
- drainage measures;
- pavement composition;
- types of shoulder;
- water content at the time of construction.

Brief comments on each of these factors are given below.

2.3.1 Subgrade Soil Type

Soils of increasing fineness and plasticity are likely to retain the greatest amounts of water (Tonkin & Taylor 1979) and to experience the greatest variation in properties. High water content in fine-grained soils generally relates to low strengths and low elastic moduli. These soils are also likely to experience significant volume changes with relatively small changes in moisture content.

Granular soils (particle size >2 mm) are less prone to changes in strength, stiffness or volume with changes in moisture content.

2.3.2 Climate

Rainfall, temperature and evaporation are the main climate factors influencing subgrade moisture conditions. Clearly, the higher the rainfall, the greater the amount of water that is available to reach the subgrade.

Temperature has less influence in the New Zealand environment. However, in cold regions of the country, temperature influences the formation and thawing of ice in the subgrade. Both the formation and the thawing of ice can have severe effects on subgrade performance.

Evaporation influences the amount of water that exists at the pavement and adjacent ground surfaces.

2.3.3 Topography

Topography is a major influence on the flow of stormwater. Generally, the steeper the topography, the greater the proportion of water shed as surface run-off instead of seeping into the ground. However, this depends greatly on the properties of the soils.

2.3.4 Water Table Depth

When the water table is reasonably high, it is one of the most significant influences on the subgrade moisture conditions (Tonkin & Taylor 1979). The depth of the water table is influenced by climate, topography, drainage provisions, and soil types.

ARRB (1991) states that a water table within 6 m of the surface in clay soils, 3 m in sandy clays or silts, or 1 m in sands is likely to have a controlling influence on the subgrade moisture conditions. Capillary rise tends to cause saturation of soils above the water table, with the height of the rise dependent on the permeability of the soil. The pore water tension, or suction, associated with capillary effects tends to increase the compressive stresses in the pavement structure.

In investigating subgrade moisture conditions, suction is considered to be the most useful parameter (Tonkin & Taylor 1979). This is because suction is a stress, which makes it more directly related to soil strength and the factors influencing subgrade moisture conditions. Pore water suction is measured in units of pF, which is the logarithm of the height (cm) that a column of water would need to rise to attain an equivalent pressure.

2.3.5 Adjacent Vegetation and Irrigation

Vegetation and/or irrigation adjacent to a pavement can have a significant influence on the subgrade moisture conditions, as both use and contribute to soil moisture.

2.3.6 Tendency to Flood

Clearly, areas that have flat, low-lying topography, and therefore a tendency to periodic flooding, are likely to have a relatively high water table.

2.3.7 Pavement Cross-section Geometry

The pavement cross section should be designed so that stormwater is shed efficiently while maintaining a suitable geometry for the safe operation of vehicles.

2.3.8 Drainage Measures

Tonkin & Taylor (1979) state that generally the four facets to pavement drainage are to:

- remove surface run-off;
- remove water from pavement layers;

- intercept water seeping from adjacent ground;
- lower the ground-water level.

Brickell (1985) recommends that drainage systems should be designed to ensure that the pavement layers do not exceed 80% saturation for extended periods of time.

2.3.9 Pavement Composition

The permeability of the pavement layers has a major influence on the moisture conditions in the subgrade. It is well established that pavement surface seals and asphalt wearing courses are not impermeable. Therefore some water can be expected to enter the pavement through its surface or the shoulder.

Tonkin & Taylor (1979) state that the pavement layers should be as impermeable as possible to prevent water entering from the subgrade. Queensland Transport (1990) states that either the base or the sub-base layer should be relatively permeable so that water entering the pavement structure can be removed laterally before it reaches the subgrade. ARRB (1991) reports that, ideally, the permeability of the pavement layers should increase with depth.

2.3.10 Types of Shoulders

A common way for water to enter a pavement structure is through the shoulder. It then seeps laterally towards the carriageway. This can be minimised by providing sealed shoulders that are at least 1 to 1.5 m wide.

2.3.11 Water Content at the Time of Construction

Powell et al. (1984) report that subgrade soils[2] that are allowed to get wet during construction generally remain wetter, and therefore weaker, than subgrades that have been kept relatively dry. They recommend that the subgrade soil should be constructed at a moisture content lower than the expected equilibrium moisture content.

Queensland Transport (1990) states that cohesive soils that are compacted when dry of optimum water content, have an open or dispersed structure. These soils generally have a high strength and stiffness. However, the dispersed structure is vulnerable to collapse, and significant loss of strength, if water is subsequently allowed to enter the subgrade soil.

A more desirable situation is to compact the soil slightly wetter than optimum so that a flocculated structure is achieved. This structure is less vulnerable to collapse on subsequent wetting.

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[2] The term ‘soil’ as used in this report is equivalent to the term ‘subgrade’.

3. Moisture in Subgrades

3.1 Mechanical Properties

If the moisture content of a subgrade soil changes for any reason, generally an associated change will occur in the soil's mechanical and volumetric properties. Basma & Al-Suleiman (1991) reported the variation in elastic modulus with increasing moisture content for various soil types and densities. As expected, the resilient modulus decreased significantly with increasing moisture content and decreasing specimen density. Regression analyses resulted in a relationship of the following general form:

$$M_r = a - (b \log_e w)$$

where: M_r = resilient modulus;
a, b = constants dependent on sample dry density;
$\log_e w$ = moisture content (natural log);

Coarse sand specimens showed the greatest decreases in elastic modulus with increasing moisture content. For example, increasing the moisture content of the test specimens from 5% to 10% resulted in reductions of approximately 40% to 80% in elastic modulus, depending on the sample dry density. The drop-off in resilient modulus for clayey soils was less, but was still quite significant. Increasing the moisture content of the clay soil specimens from 20% to 25% resulted in reductions of approximately 30% to 40% in resilient modulus, depending on the sample dry density.

The above result is slightly at odds with the results of Thadkamalla & George (1995) who carried out resilient modulus tests on various soils at different degrees and methods of saturating the soil. They found that the resilient modulus of coarse-grained soils was reduced by approximately 20% upon saturation of the specimens. For fine-grained soils, the reduction in elastic modulus was about 50% to 75% depending on both the degree and the method of saturation.

Drumm et al. (1997) performed resilient modulus tests on a number of silt and clay soil specimens. The specimens were tested at optimum moisture content (OMC) as well as at increased levels of saturation. The results were then plotted on a graph of resilient modulus in relation to percentage saturation. All specimens showed an approximately linear decrease in resilient modulus with increasing percentage saturation. The rate of decrease was measured and reported to lie in the range –280 to –2390 MPa. The soils with high Plasticity Index values generally showed the highest rate of decrease in resilient modulus.

Li & Selig (1994) investigated the effect of moisture content on resilient modulus using two scenarios: varying the moisture content with constant dry density, and varying the moisture content with constant compactive effort.

Varying the specimen moisture content with constant dry density produced the following relationship between resilient modulus and moisture content:

$$R_{m1} = 0.98 - 0.28\,(w - w_{opt}) + 0.029\,(w - w_{opt})^2$$

where: $R_{m1} = M_r / M_{r(opt)}$;
M_r = resilient modulus at moisture content w;
$M_{r(opt)}$ = resilient modulus at optimum moisture content (OMC).

Varying the specimen moisture content with constant compactive effort produced the following relationship:

$$R_{m2} = 0.96 - 0.18\,(w - w_{opt}) + 0.0067\,(w - w_{opt})^2$$

AUSTROADS (1992) reports relative subgrade support values for three soil types in relation to compaction moisture content and density, as well as soaked and unsoaked test conditions (Table 3.1).

Table 3.1 Relative subgrade support factors (from AUSTROADS 1992).

Unsoaked				4 Day Soak			
Density	**Compaction Moisture Content (relative to OMC*)**			**Density**	**Compaction Moisture Content (relative to OMC)**		
	0.9	**1**	**1.05**		**0.9**	**1**	**1.05**
Clay Soil (CH - LL > 50)							
1.05 MDD	4	3.5	3	1.05 MDD	0.9	-	-
MDD	3.5	3	2.5	MDD	0.6	1	1.5
0.95 MDD	2.5	2	2	0.95 MDD	0.4	0.6	1
Clay Soil (CL - LL < 50)							
1.05 MDD	2	-	-	1.05 MDD	1.2	2	2.2
MDD	1.8	1.2	1	MDD	0.8	1	1.1
0.95 MDD	1.2	1	1	0.95 MDD	0.5	0.5	0.6
Silty Sand Soil (SM, SL)							
1.05 MDD	4.5	-	-	1.05 MDD	-	-	-
MDD	3	1.5	-	MDD	1.2	1	0.7
0.95 MDD	1.8	1.3	1	0.95 MDD	0.6	0.5	0.5

* See Glossary for abbreviations.

Table 3.1 also shows the relationship between expected CBR values for various test conditions, with the factors being relative to the results for a soaked specimen at OMC and maximum dry density, MDD (i.e. factor equal to 1). It shows that soaking CH classification test specimens has a significant influence on the soil strength. Soaking CL, SM and SL classification soils does have an influence on the soil strength value but the effect is not as great.

The AUSTROADS data show that increasing the compaction moisture content results in reduced soil strength values for unsoaked specimens, but increased soil strength values for soaked samples.

3.2 Volumetric Properties

When the moisture content of a fine-grained soil changes, water moves into or out of the void spaces within the soil structure. The movement of water causes the void spaces to shrink or expand accordingly. Therefore, the overall volume of the soil can change significantly although the degree of saturation may stay relatively constant.

Volume changes can be minimised if the subgrade soil is compacted at a moisture content representing the conditions most likely to prevail during the life of the pavement (Queensland Transport 1990).

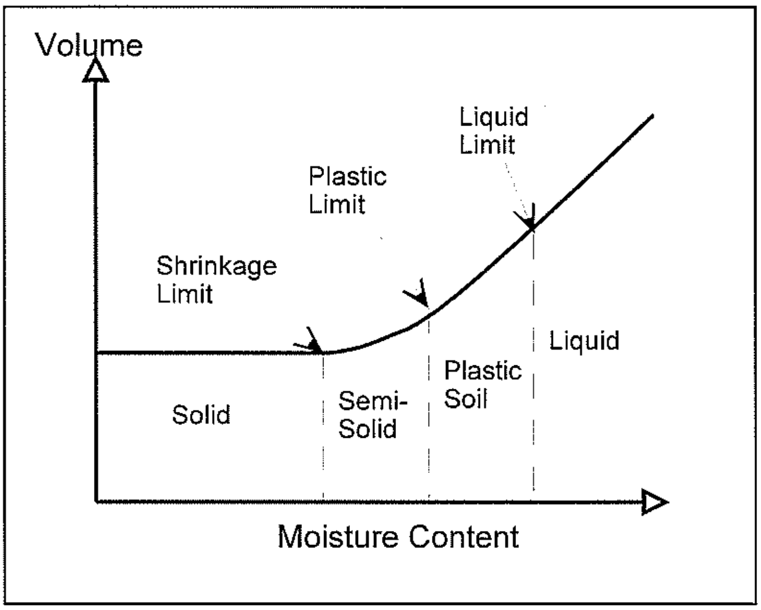

Figure 3.1 **Definition of volume change versus moisture content for plastic soils (from Capper & Cassie 1956).**

A good representation of the volume change properties of a plastic soil is that generally used to define the Atterberg Limits (see Glossary). Figure 3.1 shows how cohesive soils increase in volume as the moisture content increases, except if moisture contents are lower than the shrinkage limit (Capper & Cassie 1956).

Granular soils generally do not experience significant changes in volume with changes in moisture content. This is because the void space effectively remains constant and water is free to move into or out of the voids without an associated change in volume. For these soils the degree of saturation changes with changes in moisture content.

4. Characterisation of Subgrades for Pavement Design

4.1 General

Two main approaches are used to characterise subgrade soils for pavement design. The more conservative approach involves the performance of (generally) CBR tests with the specimens soaked for a period of approximately four days before testing. The use of soaked material parameters represents the situation where the pavement subgrade is effectively in a flooded state, i.e. saturated.

The alternative approach is to assess the subgrade performance parameters at a moisture condition other than soaked. Many pavement engineers consider this approach to be more realistic and more representative of actual pavement subgrades. However, there is a history, at least in New Zealand, of using soaked parameters, and this has become entrenched in the design philosophy.

The following sections of this report describe recommendations for subgrade moisture characterisation made in pavement design manuals from New Zealand, Australia, United States of America (US), and United Kingdom (UK).

4.2 New Zealand (Present Design Procedure)

The pavement design procedures used in New Zealand are based on those described in *Pavement Design - A Guide to the Structural Design of Road Pavements* (AUSTROADS 1992). This document is generally referred to as the AUSTROADS *Pavement Design Guide*. A supplementary document has been developed by Transit New Zealand (1995) to account for the materials and practices that are unique to New Zealand.

The AUSTROADS Pavement Design Guide defines the design moisture content (DMC) as being a "reasonable prediction of the moisture conditions in a subgrade". Soaked parameters are recommended as appropriate when the subgrade is likely to be below the ground-water table, or to be inundated for any reason.

Two methods are described for establishing the DMC when unsoaked parameters are considered to be appropriate:

- prediction from existing roads, and
- prediction from a site investigation.

4.2.1 Predicting DMC from Existing Roads

Prediction of the DMC from existing roads can be used only when the existing road and the road being designed have the following features in common:

Subgrade Soil Density where the density of the existing subgrade should be less than or equal to the density of the proposed subgrade. If this condition is not satisfied, an adjustment can be made to the field moisture content of the proposed subgrade.

Drainage Conditions where the existing and proposed pavements should be equivalent in type and position of drains, longitudinal grade, shoulder condition and crossfall, formation profile, extent of adjacent vegetation, and earthwork condition (cut or fill).

Other Considerations include the depth to the permanent water table, which should correspond between the existing and the proposed pavements. The topography and climate conditions should be similar. The seal on the existing road should have been in place for at least two years, otherwise the method may not be reliable. The compositions of the pavements in terms of layer permeability should be similar.

DMC Testing

With the above conditions satisfied, samples of the existing subgrade are taken from a depth of 300 mm below the top of the subgrade, generally in the outer wheel track. The samples are subjected to the following tests:

- Field moisture content (FMC_e);
- Plastic limit (PL_e);
- Optmum moisture content (OMC_e at standard compactive effort).

Samples of the proposed subgrade are also tested for Plastic Limit (PL_p) and Optimum Moisture Content (OMC_p). The FMC of the proposed subgrade is then calculated as the mean of the following values:

$$FMC_p = FMC_e \text{ x } OMC_p / OMC_e$$

$$FMC_p = FMC_e \text{ x } PL_p / PL_e$$

e = existing subgrade; p = proposed subgrade

The DMC is taken as the 90 percentile value of FMC_p determined from the above relationships. The DMC value may have to be corrected for seasonal variation and edge effects if such data are available.

4.2.2 Predicting DMC from Site Investigation

If an existing pavement that is sufficiently similar to the proposed pavement cannot be identified, an alternative procedure for calculating DMC can be used. This involves essentially the same procedure as that described in Section 4.2.1 of this report, except that the existing subgrade is taken as the soil on the proposed alignment. The depth of sampling depends on the depth of the water table.

4.2.3 Presumptive Subgrade CBR Values

The AUSTROADS *Pavement Design Guide* presents a table of typical presumptive subgrade CBR values which can be used for preliminary design, or when no further information is available or investigations are not warranted. Table 4.1 presents the presumptive CBR values based on soil types and drainage conditions.

Table 4.1 Presumptive subgrade CBR values (from AUSTROADS 1992).

Subgrade Description		Typical CBR Values (%)	
Material	**USC* Classification**	**Well drained**	**Poorly drained**
Highly plastic clay	CH	5	2 - 3
Silt	ML	5	2 - 3
Silty clay	CL	6 - 7	4 - 5
Sandy clay	SC	6 - 7	4 - 5
Sand	SW, SP	15 - 20	n/a

* See Glossary for abbreviations.

4.3 New Zealand (Previous Design Procedures)

Before the adoption of the AUSTROADS pavement design procedures, the previous standard for pavement design in New Zealand was the *State Highway Pavement Design and Rehabilitation Manual* (Transit New Zealand 1989). This document presented a series of charts for the design of pavement layer thicknesses. While the charts were based on a mechanistic design approach, they were quite limited in their application because the designer was constrained by the material properties and the performance criteria inherent in the charts.

The subgrade CBR was specified to be "normally soaked". If the designer was certain that saturation of the subgrade would not occur, an application could be made to Transit New Zealand for approval to use in situ moisture conditions in the characterisation of the subgrade.

4.4 Australia

The Australian pavement design procedure is described in the AUSTROADS (1992) *Pavement Design Guide*. The subgrade characterisation is that presented in Section 4.2 of this report. However, each state of Australia uses its own adaptation of different aspects of the *AUSTROADS Pavement Design Guide* to allow for conditions that are unique to the particular state. The subgrade characterisation procedures from New South Wales, Victoria and Queensland are described in the following Sections 4.4.1– 4.4.3.

4.4.1 New South Wales

The document *Supplement to the AUSTROADS Guide to the Structural Design of Road Pavements* (RTA 1992) states that a subgrade CBR for design can be obtained from an existing road providing that the subgrade soils are similar and that testing is carried out during the appropriate season.

Elastic analysis procedures are used to back-calculate the subgrade elastic modulus (or CBR). A simplified procedure using a Benkelman Beam to determine a parameter is presented called 'spreadability' in the document, along with a chart that relates spreadability and maximum Benkelman Beam deflection to CBR. The data are then subjected to a statistical analysis to obtain a confidence limit ranging from 90% to 97.5% depending on the functional class of the road.

Charts showing contours of median annual rainfall and seasonal rainfall zones throughout NSW state are presented in the document, but no description of how to apply them is given. The Supplement states that the subgrade characterisation procedure generally leads to a conservative outcome and that the data should be compared with other test procedures that do give direct measurements of subgrade conditions.

4.4.2 Victoria

The *VicRoads Guide to Pavement Design* (VicRoads 1993) is the Victorian supplement to the AUSTROADS *Pavement Design Guide*. It provides a detailed discussion of subgrade evaluation issues and drainage requirements for pavements in the state of Victoria. The pavement designer has the option of using either laboratory or field investigations to determine the properties of the subgrade for design. Where the project does not warrant detailed investigations, presumptive subgrade CBR values can be used.

The laboratory testing procedure involves carrying out CBR tests on soaked soil specimens and the result is multiplied by a Correction Factor. This factor is dependent on the magnitude of the average annual rainfall and the level of evaporation for the area in question. The supplement provides a map of Victoria showing isohyets of average annual rainfall, and areas of high evaporation (greater than 1400 mm/year) and low evaporation (less than 1400 mm/year). The Correction Factor is determined using the chart reproduced in Figure 4.1. Note that the design CBR value is limited to a maximum value of 15%.

No adjustment for rainfall (i.e. Correction Factor equals 1.0) is made in the following instances:

- urban areas where infiltration from kerb, channel or unpaved medians is likely;
- locations where the water table is within one metre of the subgrade level;
- floodways, causeways or other pavements likely to be inundated;
- pavements with porous shoulder materials;
- poorly drained subgrades;
- cuttings below the water table; or
- very impermeable subgrade materials where 4-day laboratory soaking is inappropriate.

The subgrade CBR for a pavement design can be determined in situ using Benkelman Beam, FWD or dynamic cone penetrometer (DCP) test procedures. The field investigation should be carried out after a 'representative wet period'. If this is not possible, a combination of field and laboratory testing is recommended.

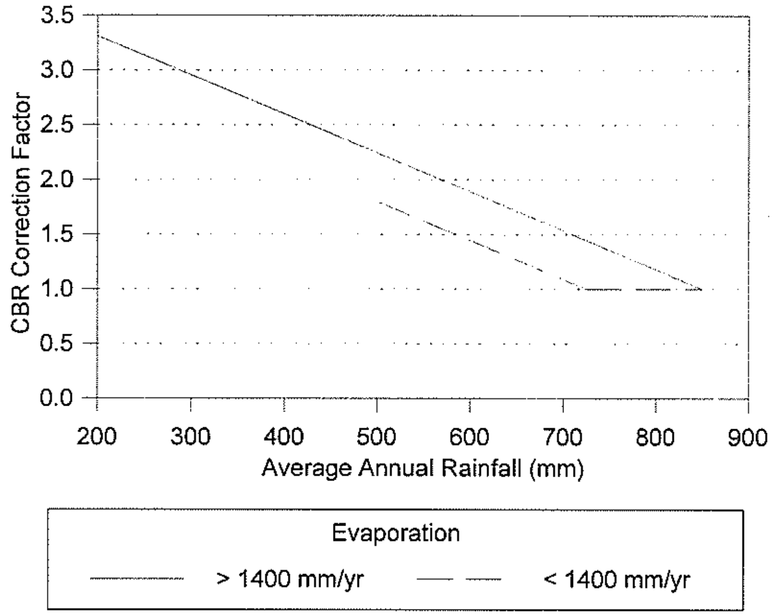

Figure 4.1 CBR Correction Factors for climate effects (from VicRoads 1993).

Table 4.2 Presumptive subgrade CBR values (from VicRoads 1993).

General Description	Design CBR
Extremely poor subgrade conditions - saturated basaltic clay areas - clays of extremely high plasticity (PI > 50) - saturated alluvial areas - silty soils subject to saturation	2
Very poor subgrade conditions - clays of very high plasticity (PI 35 - 50) - disturbed & recompacted Silurian clays - disturbed & recompacted Tertiary clays & sandy clays of high moisture content - basaltic clay areas not saturated	3
Silty subgrade soils - well drained silty soils	4
Silty clay subgrades - silty clay of very high plasticity (PI 35 - 50) - soils capable of carrying construction traffic (CBR >= 5)	3 - 5
Plastic sandy clay subgrade soils - sandy plastic clay of moderate to high plasticity (PI 15 - 35), well drained - undisturbed Silurian clays	3 - 6
Low plasticity subgrade soils - sandy clay of low to intermediate plasticity (PI 10 - 20) - well compacted silty sandy clay, sandy clay, well drained	6 - 10
Ordovician, Silurian & Devonian Sedimentary Rocks - broken & recompacted weathered rock	6 - 10

The Guide provides guidance on the use of presumptive CBR values for a range of subgrade soil types and moisture and drainage conditions. These data have been reproduced in Table 4.2.

4.4.3 Queensland

The document entitled *Pavement Design Manual* (Queensland Transport 1990) is used in conjunction with the AUSTROADS *Pavement Design Guide* for pavement design in the state of Queensland. The Manual recognises that allowance must be made for changes in subgrade moisture content that could occur from construction to in-service conditions.

The Queensland *Pavement Design Manual* is similar to the Victorian document in that the subgrade strength for design can be determined using laboratory or field testing procedures.

Three options are given for laboratory determination of the design subgrade CBR. These measure CBR:

- on specimens prepared at the DMC and a density representative of field density;
- for a range of soil moisture contents and interpolate the results for the design conditions; or
- with the specimens subjected to (four-day) soaked conditions.

The latter option is recommended when any of the circumstances outlined in Section 4.4.2 prevail, or in any situations where soaked conditions are chosen to minimise the risk of failure.

When laboratory CBR testing is carried out, the specimens should be compacted to the expected in-service condition. In cut sections the field density is recommended. In fill sections the minimum standard of compaction expected in the field is recommended. Alternatively, for expansive soils (OMC under standard compaction conditions is greater than 12%), the density after volume change has occurred is recommended for measuring CBR. If the DMC is less than OMC, then the minimum compaction standard for the subgrade (MCS) is used as the compaction standard for the test specimens. If DMC is greater than OMC then the compaction standard for the test specimens is given by:

$$(MCS) * (1 + CMC) / (1 - DMC)$$

where: MCS = minimum compaction standard;
CMC = compaction moisture content;
DMC = design moisture content.

The DMC parameter should be selected so that it realistically represents the in-service subgrade moisture conditions. Two options are given in the Queensland Manual to determine an appropriate DMC. When intensive site investigations are not warranted, the DMC can be taken from a table showing DMC values related to rainfall and drainage conditions. The table given in the Manual is presented in this report as Table 4.3. A map showing median annual isohyets for the state of Queensland is presented in the Manual.

Table 4.3 Suggested subgrade design moisture contents (from Queensland Transport 1990).

Median Annual Rainfall (mm)	Design Moisture Content (DMC)		
	Good Drainage	Poor Drainage	Conditions described in Section 4.4.2
< 500	OMC (CH & MH) otherwise 0.9 (OMC)	1.15 (OMC)	Soaked
500 - 800	OMC	1.15 (OMC)	Soaked
> 800	1.15 (OMC)	Soaked	Soaked

Alternatively, the DMC can be determined from the investigation of existing roads which have been sealed for at least two years and are similar to the proposed road with respect to:

- soil density;
- drainage conditions;
- position of the water table;
- climate; and
- pavement composition.

The Manual describes the significance of these parameters.

The investigation procedure involves recovering samples from representative sections of the existing subgrade. The samples should be taken from a depth of 300 mm or less in the outer wheel track. The following parameters are determined for each sample:

- OMC (at standard compaction);
- Moisture Content (MC);
- Liquid Limit (LL);
- Plastic Limit (PL).

For granular soils, the Effective Liquid Limit (LL_{eff}) and Effective Plastic Limit (PL_{eff}) are determined as follows:

$$LL_{eff} = F \times LL$$
$$PL_{eff} = F \times PL$$

where F = fraction passing the 0.425 mm sieve.

The DMC is then determined using a procedure equivalent to that described in Section 4.2.1.

Field testing for subgrade strength properties can be carried out on an existing road which has been sealed for at least two years and which has soils with similar type, density and moisture conditions as the proposed road. The testing is carried out at the wettest time of the year using in situ CBR or DCP procedures. If it is not possible to perform the tests after a wet period, then a combination of laboratory and field testing is recommended.

The Manual also provides guidance on the use of presumptive CBR values for a range of subgrade soil types and moisture/drainage conditions. This data has been reproduced in the following Table 4.4.

Table 4.4 Presumptive subgrade CBR values (from Queensland Transport 1990).

No.	General Description	Design CBR
1	Highly plastic (CH) clays; annual rainfall < 300 mm; good drainage	10
2	Highly plastic (CH) clays; annual rainfall 300 - 500 mm; good drainage	7
3	Highly plastic (CH) clays & silts (MH); annual rainfall > 500 mm; good drainage	5
4	Highly plastic (CH) clays & silts (MH); poor drainage	3
5	Silty clays (CL), sandy clays (SC) sandy loam (SM, ML); poor drainage	5
6	Silty clays (CL), sandy clays (SC) sandy loam (SM, ML); good drainage	7
7	Loose, non-plastic sand (SW, SP); poor drainage	7
8	Dense, non-plastic sand (SW, SP); poor drainage	10
9	Dense, non-plastic sand (SW, SP); good drainage	16
10	Extremely to highly weathered rocks likely to weather or degrade during construction to form clayey or silty materials	Treat as for 1 - 4 above*
11	Extremely to highly weathered rocks likely to form gravelly clays (GC) or clayey sands (SC) during construction; poor drainage	7 - 10
12	Extremely to highly weathered rocks likely to form gravelly clays (GC) or clayey sands (SC) during construction; good drainage	10 -15

4.5 United States of America

The procedures used for the design of road pavements in the US are described in the document *AASHTO Guide for Design of Pavement Structures* (AASHTO 1993). The AASHTO Guide recognises that the environmental factors of moisture and temperature have a major influence on the performance of pavement layers.

The AASHTO pavement design procedure is based on the solution of a complex relationship between a parameter called Structural Number (SN) and a range of other parameters including:

- traffic loading;
- pavement serviceability;
- subgrade resilient modulus; and
- design reliability.

The AASHTO Guide states that the level of subgrade support can vary from season to season throughout the year. Therefore, for the purposes of pavement design, the subgrade is characterised using the mean effective resilient modulus. This represents the subgrade resilient modulus that produces the same change in pavement serviceability over the year as if separate elastic moduli were used for each season.

Calculation of the effective resilient modulus requires knowledge of the seasonal variation of resilient modulus for a subgrade soil. This can be achieved using either a laboratory or a field testing approach. The laboratory approach involves testing specimens over a range of moisture contents to establish a relationship between moisture content and resilient modulus. The field subgrade moisture content is then estimated for the year on a monthly or two-monthly basis. This establishes the seasonal variation of the resilient modulus. Alternatively, the seasonal variation of resilient modulus can be determined using back-analysis of deflection bowls by FWD.

Once the seasonal variation of resilient moduli has been established, the variation is further broken down into monthly or two-monthly intervals. The effective resilient modulus is determined using factors of relative damage which are provided in the AASHTO Guide.

The AASHTO Guide also provides design information for flexible pavements carrying low traffic volumes. It provides suggested subgrade effective resilient moduli as shown in Table 4.5.

Table 4.5 Suggested effective subgrade resilient moduli for low traffic volume roads (after AASHTO 1993).

Climate Region[1]	**Characteristics**	**Subgrade Resilient Modulus at Various Levels of Subgrade Soil Quality** [2] **(MPa)**				
		V. Poor	**Poor**	**Fair**	**Good**	**V.Good**
I	Wet, no freeze	19	26	34	47	66
II	Wet, freeze - thaw cycle	19	23	31	38	50
III	Wet, hard freeze, spring thaw	19	21	28	30	39
IV	Dry, no freeze	22	28	39	54	81
V	Dry, freeze - thaw cycle	21	26	34	41	57
VI	Dry, hard freeze, spring thaw	19	21	28	31	39

[1] Climate regions I, II, III, IV, V, VI (are as in AASHTO 1993).
[2] Values converted from imperial units.

TRB (2000) report that the AASHTO Guide is due for updating in 2002. One of the areas of concern in the current Guide is how the climate factors are used in the analysis of pavement performance. This is because the current AASHTO design procedure is largely based on data obtained from the earlier AASHO Road Test which involved the use of a single subgrade soil type and a single set of climatic conditions.

4.6 United Kingdom

The UK design procedure is presented in TRRL LR 1132, *The Structural Design of Bituminous Roads* (Powell et al. 1984). The design philosophy for the subgrade involves two phases: a construction phase, and an in-services phase.

Construction phase
The subgrade acts as the foundation for a haul road for construction traffic. The subgrade moisture content is considerably influenced by the conditions during construction.

In-service phase
The subgrade acts as the long-term foundation for the road. Equilibrium moisture conditions are attained, although they are influenced by the construction conditions.

Figures 4.2 and 4.3 (from Powell et al. 1984) show how the subgrade CBR may vary with Plasticity Index during the construction and in-service phases respectively.

The properties of subgrade soils are very dependent upon moisture conditions and disturbance. Powell et al. state that estimation or measurement of CBR values for remoulded subgrade specimens is a sensible though somewhat conservative approach. Table 4.6 shows presumptive CBR values under typical equilibrium moisture conditions.

Figure 4.2 Subgrade CBR versus Plasticity Index during construction phase.

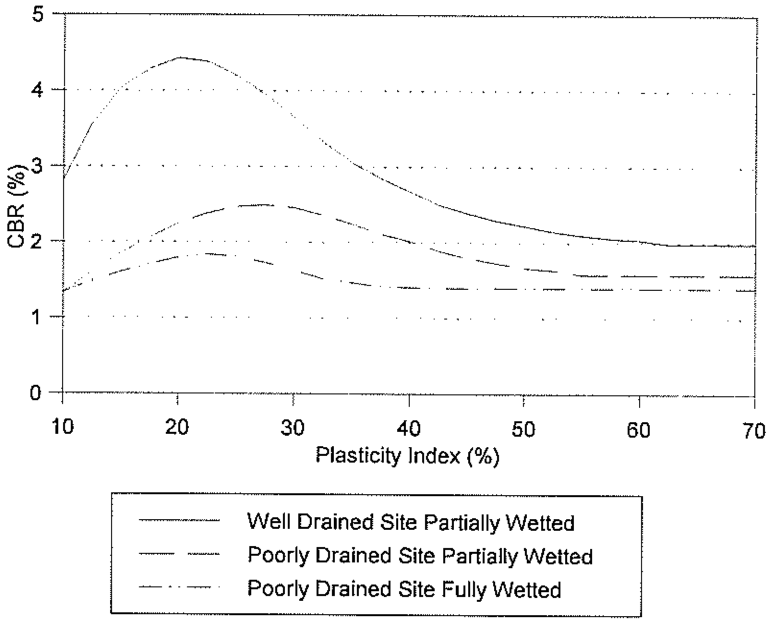

Figure 4.3 Subgrade CBR versus Plasticity Index during in-service phase.

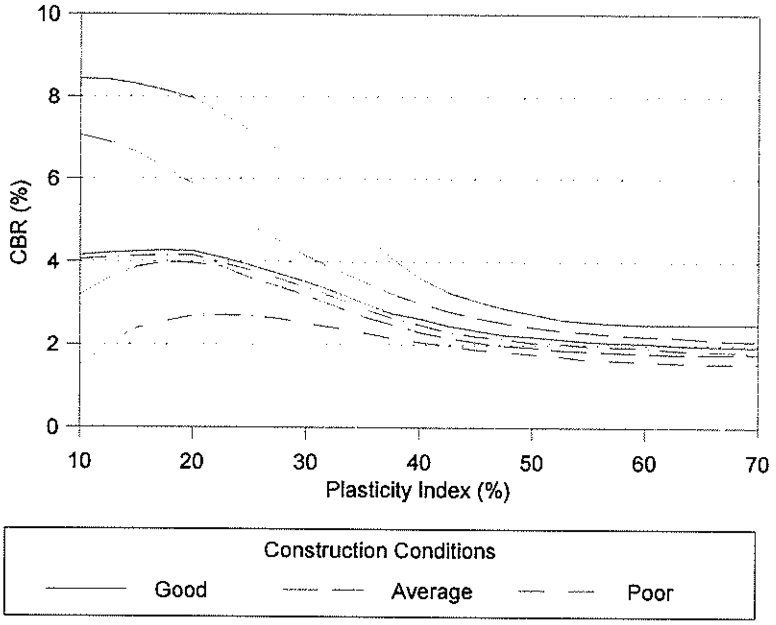

Table 4.6 Estimated CBR values for British soils under equilibrium moisture conditions (from Powell et al. 1984).

Soil Type	Plasticity Index	CBR (%)											
		High Water Table(1)						Low Water Table(2)					
		Construction Conditions						Construction Conditions					
		Poor		Average		Good(3)		Poor		Average		Good(3)	
		Thin(4)	Thick(5)	Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick	Thin	Thick
Heavy clay	70	1.5	2	22	22	2	2	1.5	2	22	22	22	2.5
	60	1.5	2	23	3	2	2.5	1.5	2	23	3	23	2.5
	50	1.5	2			2	2.5	2	2	45		46	2.5
	40	2	2.5			2.5	3	2.5	2.5	5		6	3.5
Silty clay	30	2.5	3.5			3.5	5	3	3.5				6
Sandy clay	20	2.5	4			4.5	7	3	4				8
	10	1.5	3.5			3.5	7	2.5	4				>8
Silt	-	1	1	1	1	2	2	1	1	2	2	2	2
Sand (poor graded)	-	20	20	20	20	20	20	20	20	20	20	20	20
Sand (well graded)	-	40	40	40	40	40	40	40	40	40	40	40	40
Sandy gravel (well graded)	-	60	60	60	60	60	60	60	60	60	60	60	60

Notes (1) High Water Table infers water table is 300 mm below subgrade formation level.
(2) Low Water Table infers water table is 1 m below subgrade formation level.
(3) Good Construction Conditions infers subgrade is never wetter than equilibrium moisture content.
(4) Thin Pavement infers total thickness < 300 mm.
(5) Thick Pavement infers total thickness > 1200 mm (including capping).

5. Field Investigation Methodology

5.1 General

Three sealed pavements in the Auckland area were selected for the field investigations. They were subjected to a range of tests to determine if any seasonal variation of subgrade moisture occurred and, if so, its influence on the subgrade strength properties.

5.2 Test Pavement Selection

Asset Managers from Auckland and Waitakere City Councils were asked for approval to carry out the (destructive) testing programme on three streets within their council boundaries. The objective was to identify three streets that had been in service for a reasonable period of time (at least 5 years) and, if possible, that covered a range of pavement types and expected moisture regimes. Descriptions of the three pavements selected for the field investigation follow.

Kohimarama Road, Auckland City
Kohimarama Road is a busy arterial road located in the eastern Auckland suburb of Kohimarama (Figure 5.1). The road pavement alignment generally follows a ridge with a gentle decline from south to north. The carriageway width is 9.2 m and the edges comprise kerbs and channels. The pavement has a dense asphaltic concrete surface and has a grassed berm on one side of the road. The surrounding ground is slightly lower than the road and generally falls away from it.

The test section is located on the northbound side of Kohimarama Road between Commins Crescent and Selwyn Avenue.

Blockhouse Bay Road, Auckland City
Blockhouse Bay Road is a busy arterial road located in the western Auckland suburb of Avondale (Figure 5.2). The pavement alignment generally follows rolling topography in a north–south direction. The carriageway width is 10.1 m and the edges comprise kerbs and channels. The pavement has a dense asphaltic concrete surface and a narrow grassed berm on one side of the road. The surrounding ground rises slightly on the eastern side of the carriageway and is approximately level with the carriageway on the western side.

The test section is located on the southbound side of Blockhouse Bay Road between St Jude Street and New Windsor Road.

Bristol Road, Waitakere City
Bristol Road is a quiet rural road (Figure 5.3) located in Whenuapai, north-west of Auckland City. The pavement alignment falls slightly from south to north. The surrounding ground is generally flat and level with the carriageway. Shallow side drains are provided on both sides of the carriageway.

The test section is located immediately north of Dale Road. The carriageway width is 5.5 m and the edges are unsealed.

Figure 5.1 General view of Kohimarama Road test site, looking north.

Figure 5.2 General view of Blockhouse Bay Road test site, looking north.

Figure 5.3 General view of Bristol Road test site, looking north.

5.3 Field and Laboratory Testing

Field tests were carried out at three longitudinal locations at each test section. At each of the three locations, tests were carried out in two transverse locations in the left wheel track (LWT) and at the carriageway centreline. Details of the test locations for the three test sections are presented in Table 5.1.

Pavement pits were excavated to subgrade level at each test location. Boreholes were hand-augered from the top of the subgrade to a depth of 1.5 m. The suites of tests shown in Table 5.2 were carried out on the subgrade materials.

The initial objective was to carry out the main suite of tests in four rounds of testing to incorporate seasonal variations, i.e. during two consecutive summer and winter periods. However, difficulties associated with laboratory testing resources meant that the four rounds of testing were somewhat irregular. Each round of testing involved opening the same test pit and carrying out the successive tests in a square pattern within approximately 0.75 m of each other. The pits were reinstated at the completion of each round of tests.

Table 5.1 Details of pavement pit locations.

Test Section	Pavement Pit	Longitudinal Location	Transverse Location
Kohimarama Road	KO1	Outside House No. 154	LWT, Northbound Lane
	KO2		Centre of Carriageway
	KO3	Outside House No. 148	LWT, Northbound Lane
	KO4		Centre of Carriageway
	KO5	Outside House No. 142	LWT, Northbound Lane
	KO6		Centre of Carriageway
Blockhouse Bay Road	BB1	Outside House No. 163	LWT, Southbound Lane
	BB2		Centre of Carriageway
	BB3	Outside House No. 180	LWT, Southbound Lane
	BB4		Centre of Carriageway
	BB5	Outside House No. 175	LWT, Southbound Lane
	BB6		Centre of Carriageway
Bristol Road	BR1	42 m From House No. 2	LWT, Northbound Lane
	BR2		Centre of Carriageway
	BR3	50 m From BR1	LWT, Northbound Lane
	BR4		Centre of Carriageway
	BR5	50 m From BR2	LWT, Northbound Lane
	BR6		Centre of Carriageway

Table 5.2 Summary of test methods, locations and frequencies.

Test Parameter	Test Method*	Test Locations	Test Frequency
In situ CBR(1)	NZS 4402:1986 Test 6.1.3	All	Four times
DCP(2)	NZS 4402:1988 Test 6.5.2	All	Four times
Water Content	NZS 4402:1986 Test 2.1	All	Four times
Pit Log / Photo	NZ Geomechanics Society	All	Four times
Lab CBR (Soaked)	NZS 4402:1988 Test 6.1.1	Each LWT pit	Once only
Liquid Limit	NZS 4402:1986 Test 2.2	Each soil type	Once only
Plastic Limit	NZS 4402:1986 Test 2.2	Each soil type	Once only
Plasticity Index	NZS 4402:1986 Test 2.2	Each soil type	Once only
Bulk Density	NZS 4402:1986 Test 5.1.4	Each soil type	Once only
Ground-water Level	Standpipe & Dipmeter	One per site	Each month

Notes: (1) California Bearing Ratio; (2) Dynamic Cone Penetrometer
* NZS 4402 tests are listed in References.

6. Results

6.1 Kohimarama Road

6.1.1 Pavement Materials

Detailed pavement pit logs are presented in Appendix 1, and the typical pavement structure is summarised as follows:

Surface: 40 to 110 mm of asphalt in one or more layers - in good condition.

Basecourse: 60 to 140 mm of AP40 basecourse (some crushed scoria) - dense and slightly moist.

Sub-base: 200 to 250 mm of silty gravel - dense to very dense and slightly moist.

Subgrade: Silty clay, sometimes overlying clay - stiff to very stiff, medium to high plasticity (Plasticity Index in the range 30 to 74), slightly moist.

The depth to the subgrade ranged from 300 mm (at KO5) to 500 mm (at KO4).

6.1.2 Water Content Tests

Samples of subgrade were recovered from the test locations for laboratory water content testing. Figures 6.1(a) to 6.1(f) show plots of water content versus depth into the subgrade for each test location (KO1-KO6) and all four rounds of testing, carried out in December 2000, April and October 2001, and February 2002.

6.1.3 Dynamic Cone Penetrometer Data

The results of the first round of DCP tests are shown on the test pit logs presented in Appendix 1. The results at each test location for all four rounds of testing are presented in Figures 6.2(a) to 6.2(f). The plots show cumulative DCP blows versus depth into the subgrade.

6.1.4 In Situ CBR Tests

The in situ CBR tests were carried out at the surface of the subgrade at each test location. The results of the four rounds of testing at each test location are shown in Figure 6.3.

6.1.5 Laboratory CBR Tests

Laboratory (soaked) CBR tests were carried out using remoulded specimens (using standard compaction) of soil taken from the top 200 mm of the subgrade of pits KO1, KO3 and KO5. The tests were carried out in June 2002, and the results are presented in Table 6.1 (p.39).

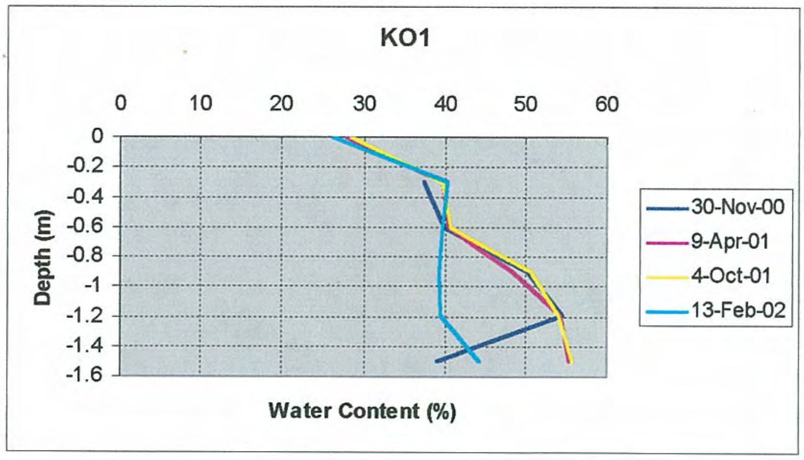

Figure 6.1(a) Subgrade water content profile - Pit KO1.

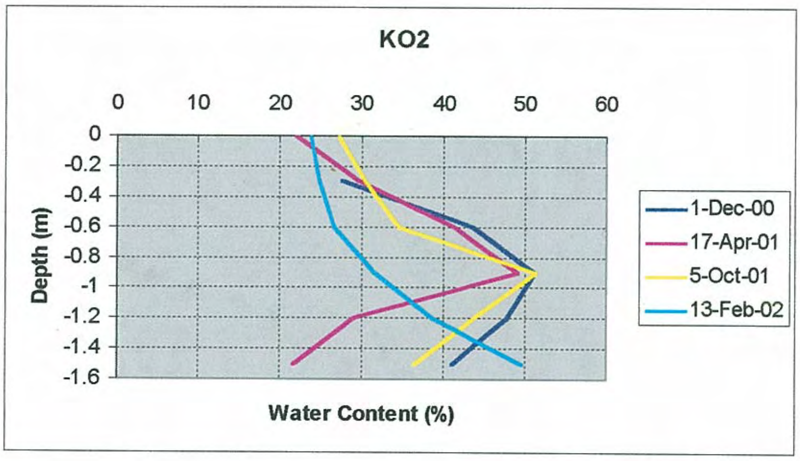

Figure 6.1(b) Subgrade water content profile - Pit KO2.

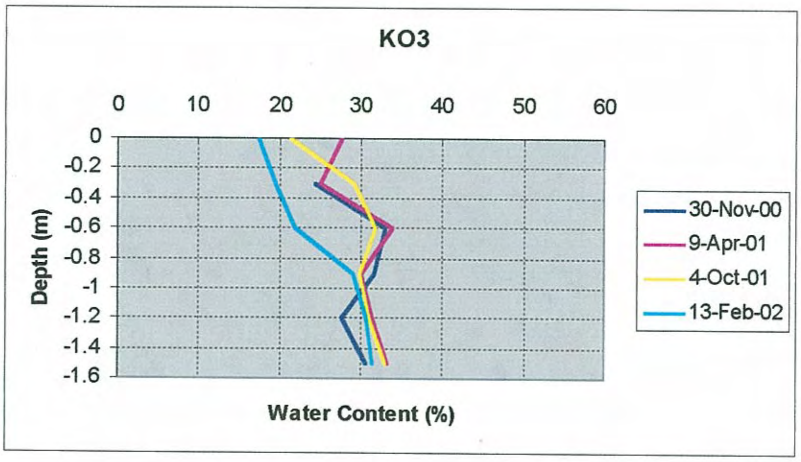

Figure 6.1(c) Subgrade water content profile - Pit KO3.

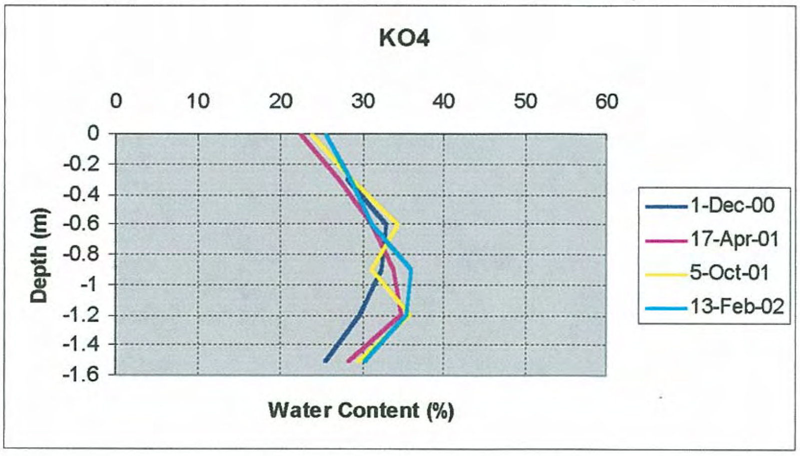

Figure 6.1(d) Subgrade water content profile - Pit KO4.

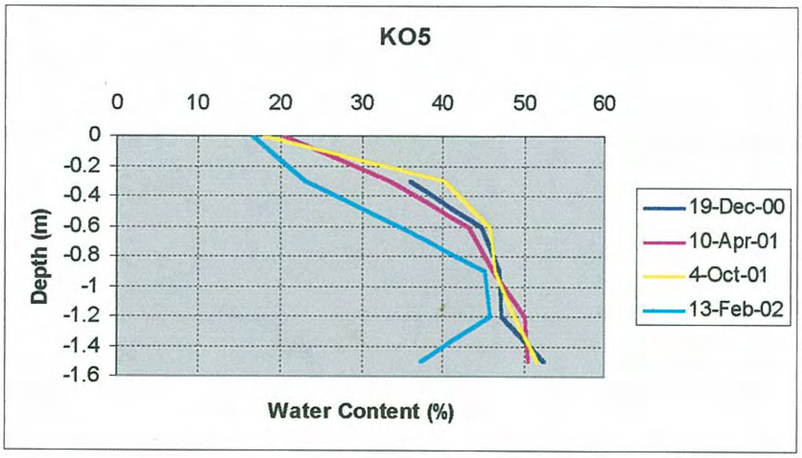

Figure 6.1(e) Subgrade water content profile - Pit KO5.

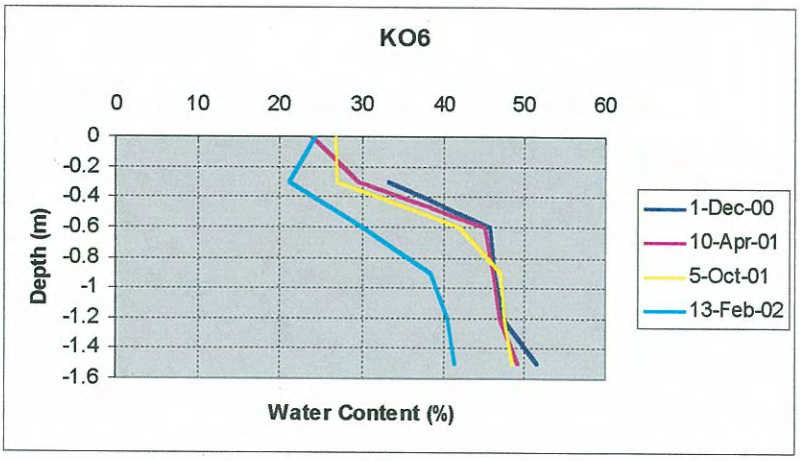

Figure 6.1(f) Subgrade water content profile - Pit KO6.

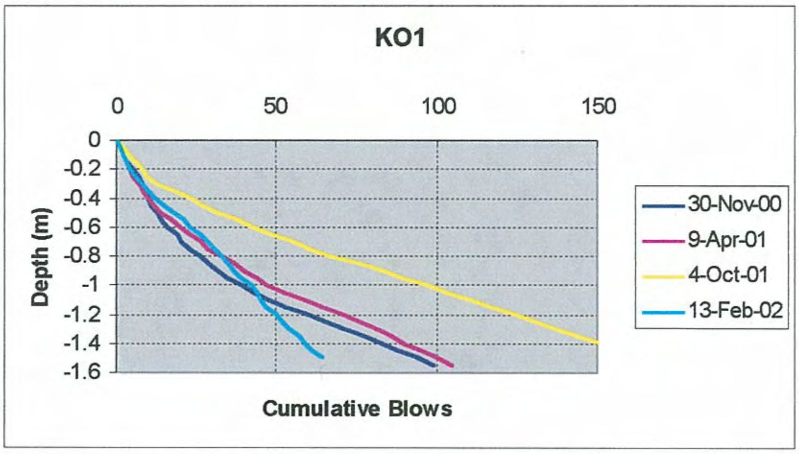

Figure 6.2(a) Subgrade DCP cumulative blows versus depth - Pit KO1.

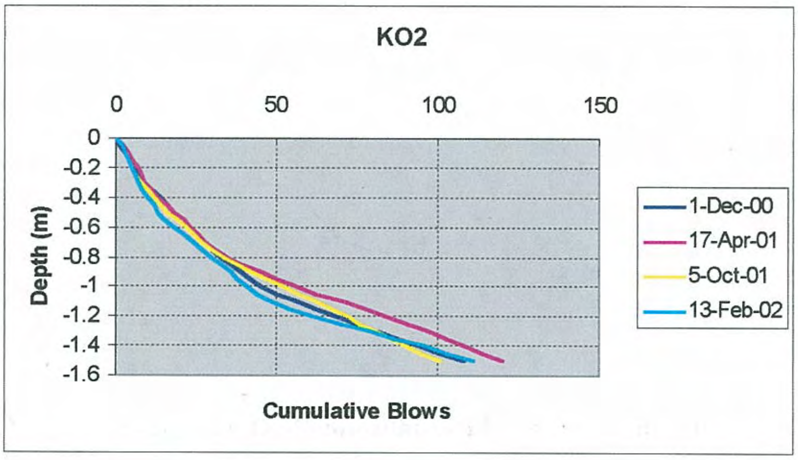

Figure 6.2(b) Subgrade DCP cumulative blows versus depth - Pit KO2.

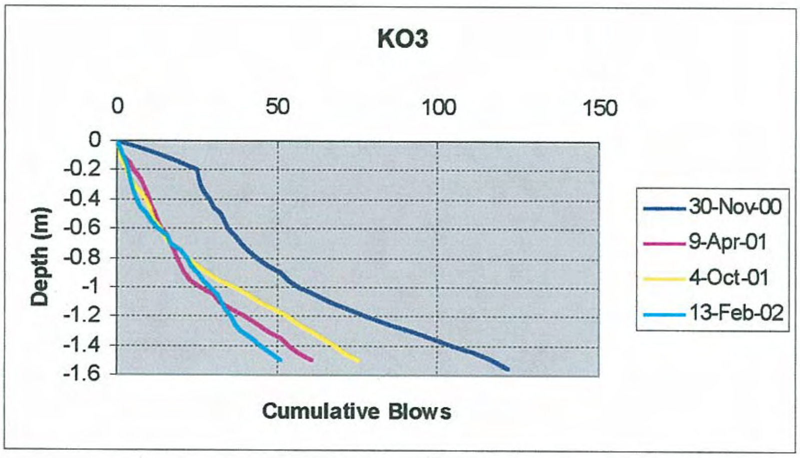

Figure 6.2(c) Subgrade DCP cumulative blows versus depth - Pit KO3.

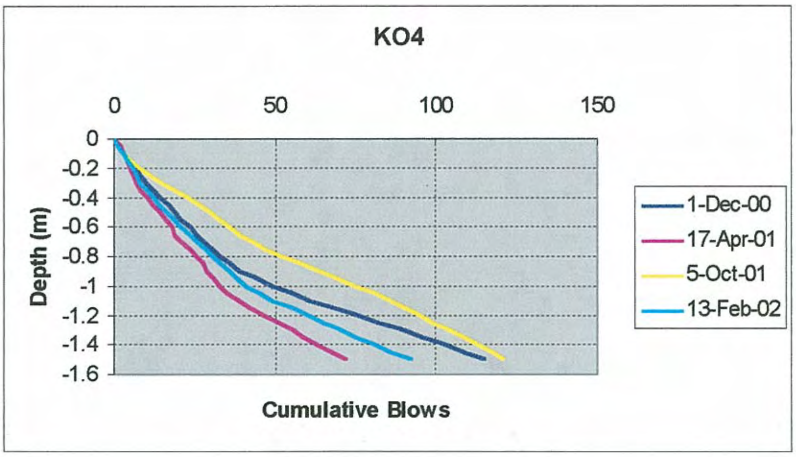

Figure 6.2(d) Subgrade DCP cumulative blows versus depth - Pit KO4.

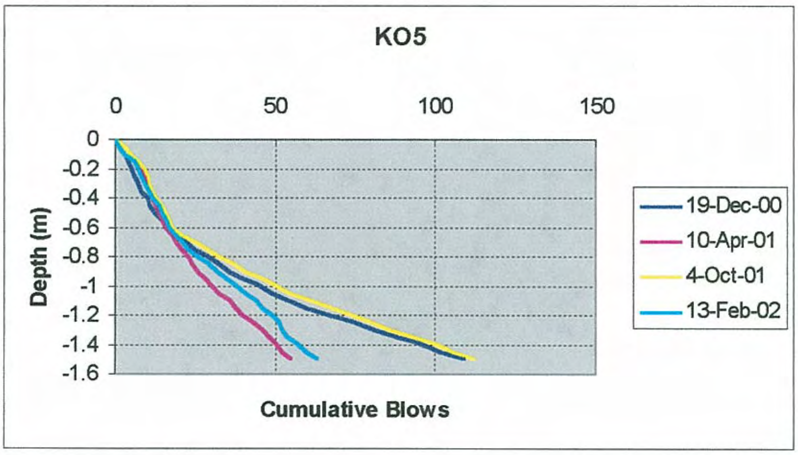

Figure 6.2(e) Subgrade DCP cumulative blows versus depth - Pit KO5.

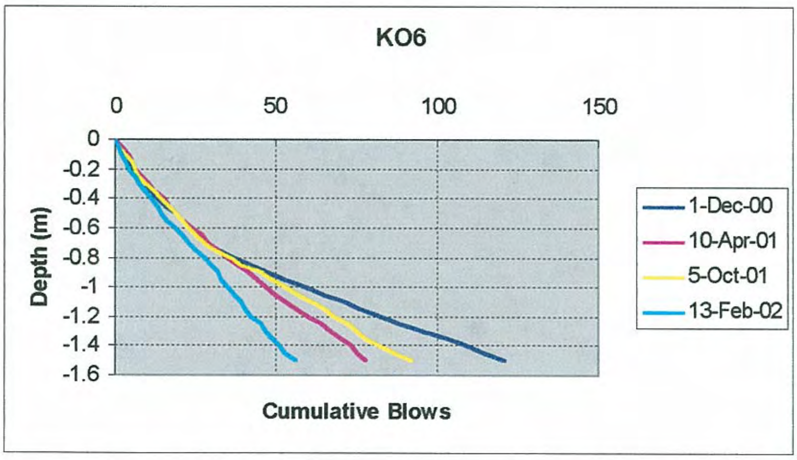

Figure 6.2(f) Subgrade DCP cumulative blows versus depth - Pit KO6.

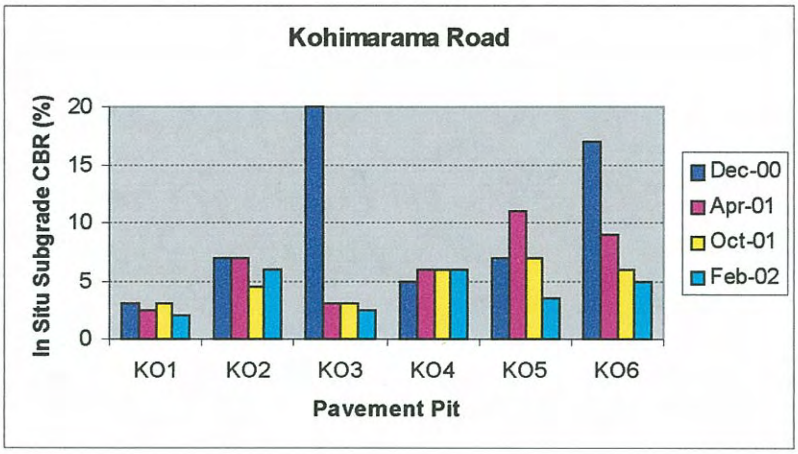

Figure 6.3 In situ subgrade CBR for each round of testing, at Kohimarama Road.

Table 6.1 Laboratory (soaked) CBR tests for Kohimarama Road test specimens.

Test Pit	KO1	KO3	KO5
Initial Water Content (%)	32.6	19.4	20.6
Compacted Dry Density (t/m^3)	1.42	1.74	1.70
Final Water Content (%)	33.1	19.8	21.1
Swell (%)	0.2	0	0.4
CBR (%)	2	2	1.5

6.1.6 Ground-water Level Measurements

A standpipe was installed at KO5 to a depth of 1.8 m below the top of the pavement and it was dipped on a monthly basis from February 2001 until February 2002. The ground-water level was not encountered during the monitoring period.

6.2 Blockhouse Bay Road

6.2.1 Pavement Materials

Detailed pavement pit logs are presented in Appendix 1, and the typical pavement structure is summarised as follows.

Surface: 70 to 90 mm of asphalt and chip seal in several layers - in reasonable condition.

Basecourse: 0 to 130 mm of AP40 basecourse - dense to very dense and slightly moist.

Sub-base: 200 to 370 mm of AP100 scoria gravel with silt matrix - very dense and dry to slightly moist.

Subgrade: Clayey silt and silty clay layers - firm tending to stiff and very stiff with increasing depth, low to medium plasticity (Plasticity Index in the range 27 to 39), slightly moist to moist.

The depth to the subgrade ranged from 400 to 450 mm.

6.2.2 Water Content Tests

Samples of subgrade were recovered from the test locations for laboratory water content testing. Figures 6.4(a) to 6.4(f) show plots of water content versus depth into the subgrade for each test location (BB1-BB6) and all four rounds of testing, carried out on 14 and 18 December 2000, 18 April–3 May 2001, 8-18 October 2001, 14-21 February 2002.

6.2.3 Dynamic Cone Penetrometer Data

The results of the first round of DCP tests are shown on the test pit logs presented in Appendix 1. The results for all four rounds of testing at each test location are presented in Figures 6.5(a) to 6.5(f). The plots show cumulative DCP blows versus depth.

6.2.4 In Situ CBR Tests

The in situ CBR tests were carried out at the surface of the subgrade at each test location. The results of the four rounds of testing at each test section are shown in Figure 6.6 (p.45).

6.2.5 Laboratory CBR Tests

Laboratory (soaked) CBR tests were carried out using remoulded specimens (with standard compaction) using soil taken from the top 200 mm of the subgrade of pits BB1, BB3 and BB5. The tests were carried out in June 2002, and the results are presented in Table 6.2 (p.45).

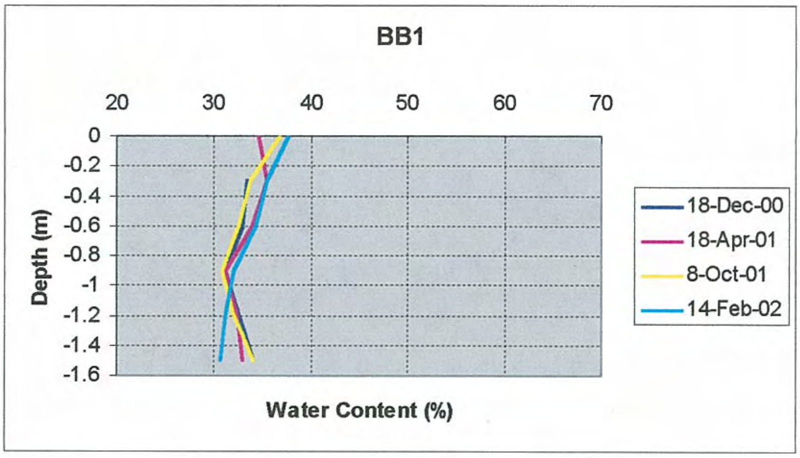

Figure 6.4(a) Subgrade water content profile - Pit BB1.

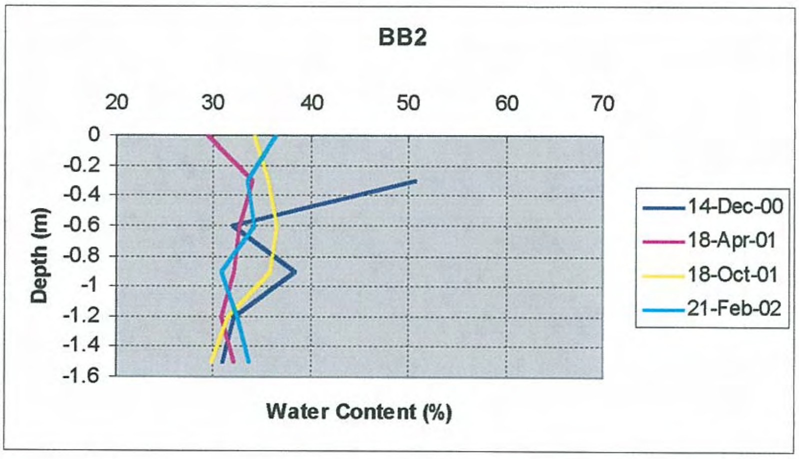

Figure 6.4(b) Subgrade water content profile - Pit BB2.

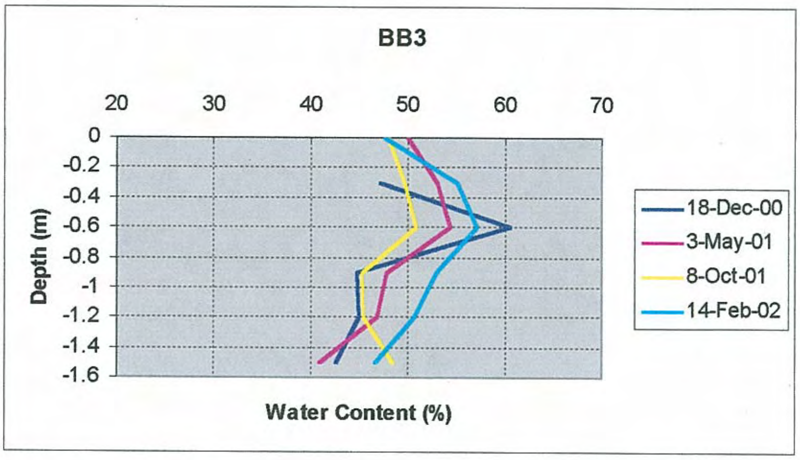

Figure 6.4(c) Subgrade water content profile - Pit BB3.

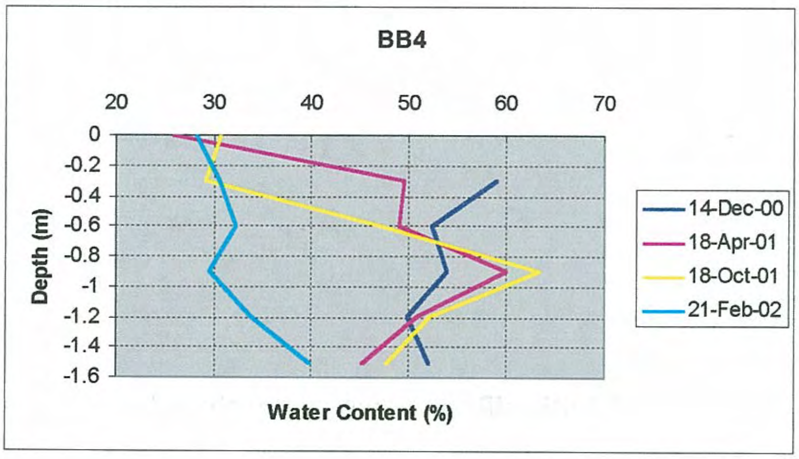

Figure 6.4(d) Subgrade water content profile - Pit BB4.

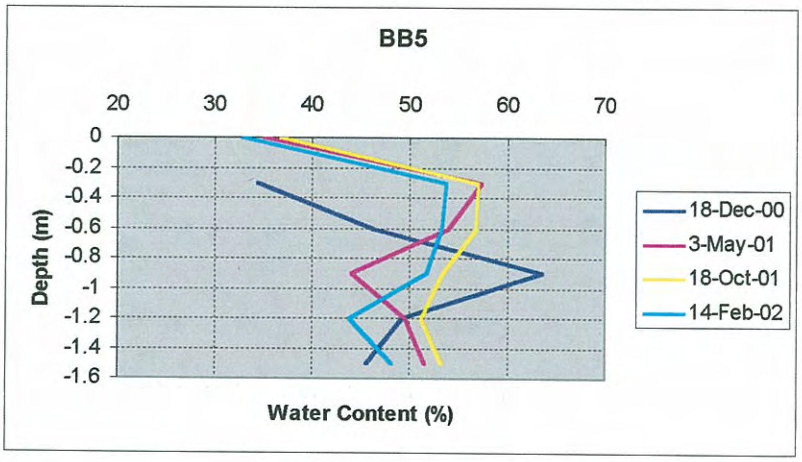

Figure 6.4(e) Subgrade water content profile - Pit BB5.

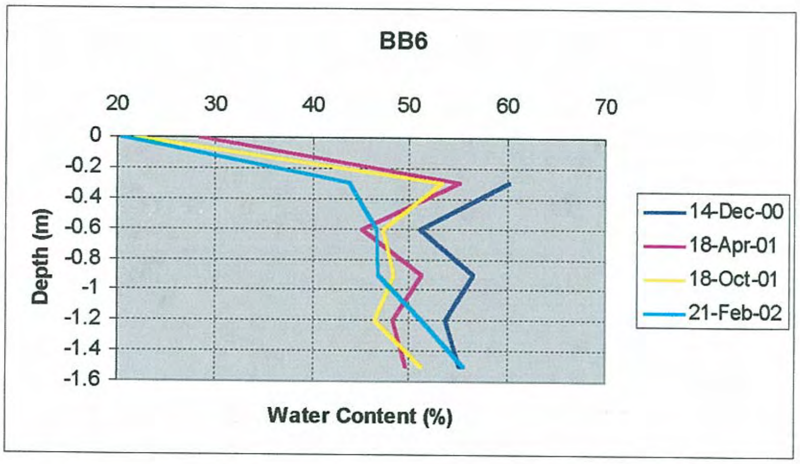

Figure 6.4(f) Subgrade water content profile - Pit BB6.

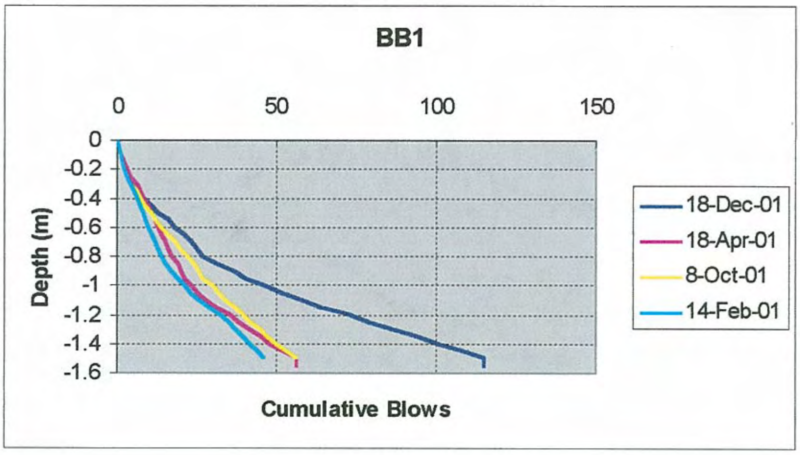

Figure 6.5(a) Subgrade DCP cumulative blows versus depth - Pit BB1.

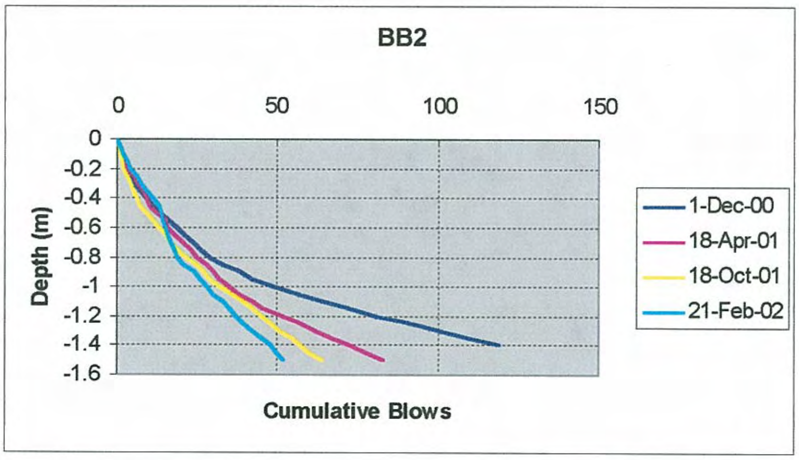

Figure 6.5(b) Subgrade DCP cumulative blows versus depth - Pit BB2.

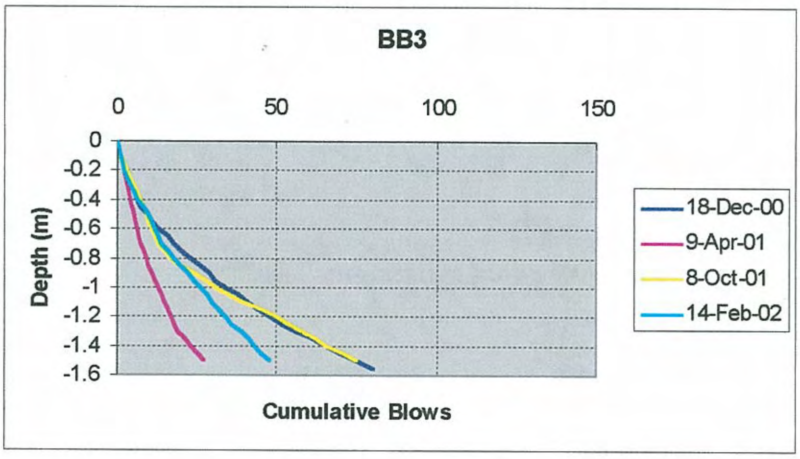

Figure 6.5(c) Subgrade DCP cumulative blows versus depth - Pit BB3.

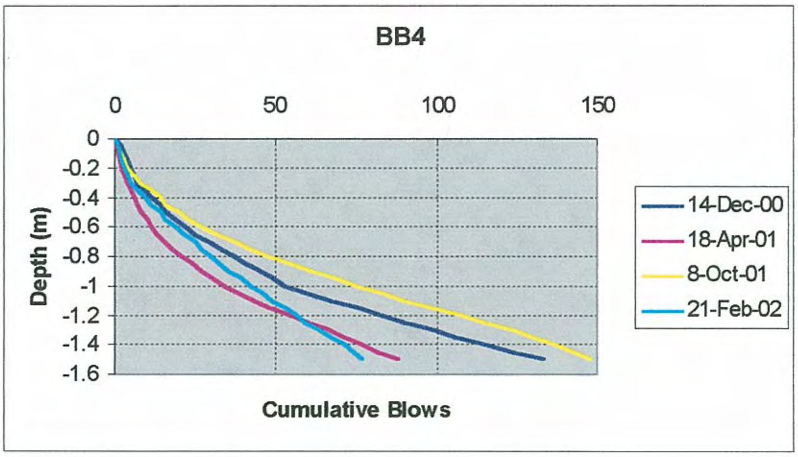

Figure 6.5(d) Subgrade DCP cumulative blows versus depth - Pit BB4.

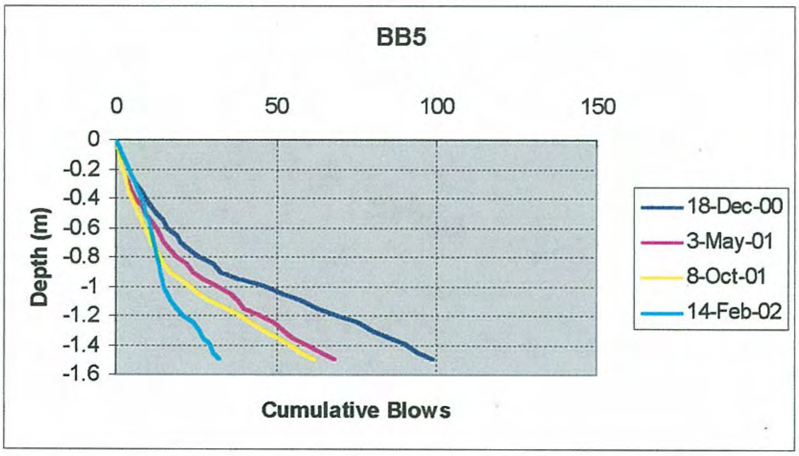

Figure 6.5(e) Subgrade DCP cumulative blows versus depth - Pit BB5.

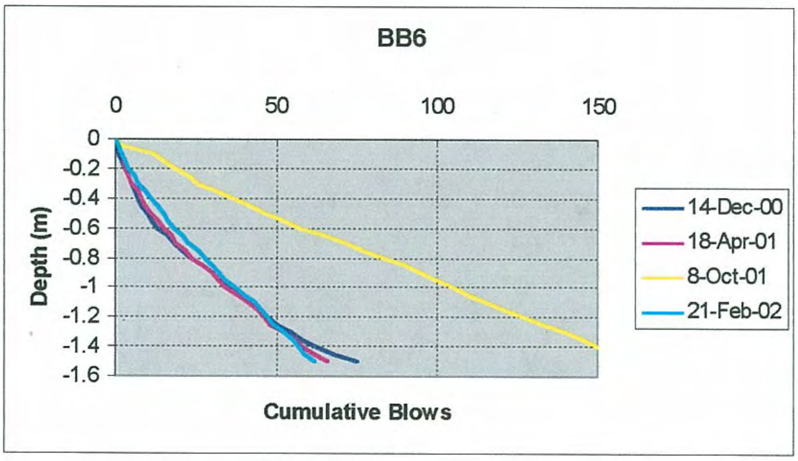

Figure 6.5(f) Subgrade DCP cumulative blows versus depth - Pit BB6.

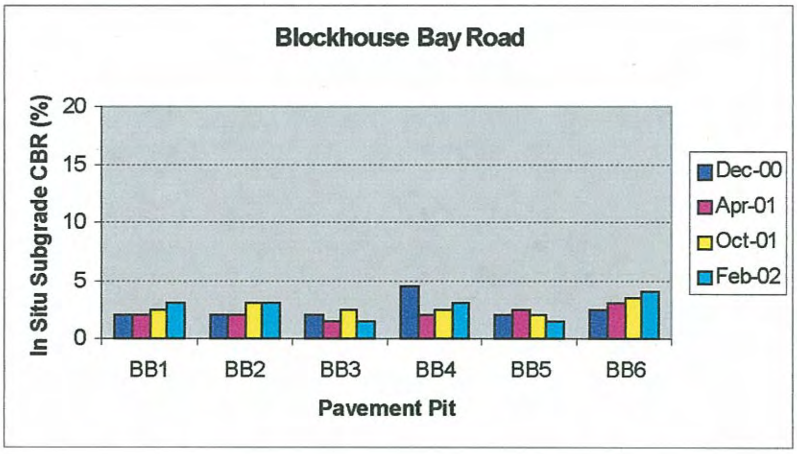

Figure 6.6 In situ subgrade CBR for each round of testing, at Blockhouse Bay Road.

Table 6.2 Laboratory (soaked) CBR tests for Blockhouse Bay Road test specimens.

Test Pit	BB1	BB3	BB5
Initial Water Content (%)	34.7	48.7	49.4
Compacted Dry Density (t/m^3)	1.34	1.14	1.14
Final Water Content (%)	37.6	51.1	50.2
Swell (%)	0.2	1.4	0.2
CBR (%)	1.5	1.5	1.5

6.2.6 Ground-water Level Measurements

A standpipe was installed at BB5 to a depth of 1.85 m below the top of the pavement, and it was dipped on a monthly basis from February 2001 until February 2002. The ground-water level was not encountered during the monitoring period.

6.3 Bristol Road

6.3.1 Pavement Materials

Detailed pavement pit logs are presented in Appendix 1, and the typical pavement structure is summarised as follows:

Surface: 25 mm of chipseal (Grade 3&4) - in reasonable condition.

Basecourse: 115 to 175 mm of AP40 basecourse - dense to very dense, slightly moist, plastic clayey matrix in places, query stabilised.

Sub-base: 0 to 230 mm of silty AP40 - medium dense to dense and slightly moist.

Subgrade: Silt, getting clayey with increasing depth - soft to very stiff, low to high plasticity (Plasticity Index in the range 32 to 63), slightly moist to moist.

The depth to the subgrade ranged from 150 mm (BR1) to 370 mm (BR6).

6.3.2 Water Content Tests

Samples of subgrade were recovered from the test locations for laboratory water content testing. Figures 6.7(a) to 6.7(f) show plots of water content versus depth into the subgrade for each test location (BR1 - BR6) and all four rounds of testing, carried out on 6 and 15-16 December 2000, 19 April and 1 May 2001, 25 September 2001, and 14 and 21 February 2002.

6.3.3 Dynamic Cone Penetrometer Data

The results of the (first round of) DCP tests are shown on the test pit logs presented in Appendix 1. The results for all four rounds of testing at each test location are presented in Figures 6.8(a) to 6.8(f). The plots show cumulative DCP blows versus depth.

6.3.4 In Situ CBR Tests

The in situ CBR tests were carried out at the surface of the subgrade at each test location. The results of the four rounds of testing at each test location are shown in Figure 6.9 (p.51).

6.3.5 Laboratory CBR Tests

Laboratory (soaked) CBR tests were carried out using remoulded specimens (with standard compaction) using soil taken from the top 200 mm of the subgrade of pits BR1, BR3 and BR5. The tests were carried out in June 2002, and the results are presented in Table 6.3.

Table 6.3 Laboratory (soaked) CBR tests for Bristol Road test specimens.

Test Pit	BR1	BR3	BR5
Initial Water Content (%)	71.4	54.2	53.3
Compacted Dry Density (t/m^3)	0.9	1.02	1.0
Final Water Content (%)	73.2	60.3	55.4
Swell (%)	0.2	0	0
CBR (%)	9	10	1.5

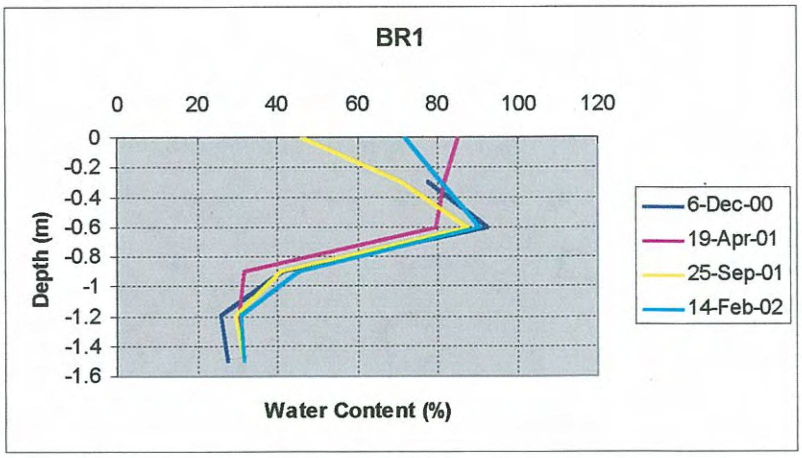

Figure 6.7(a) Subgrade water content profile - Pit BR1.

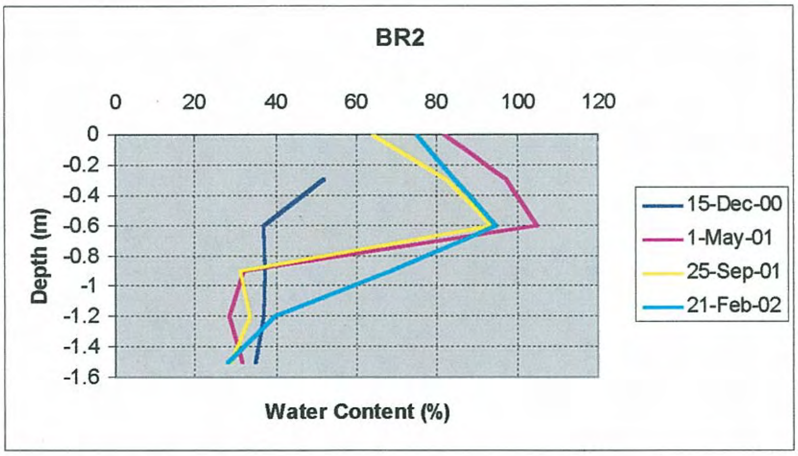

Figure 6.7(b) Subgrade water content profile - Pit BR2.

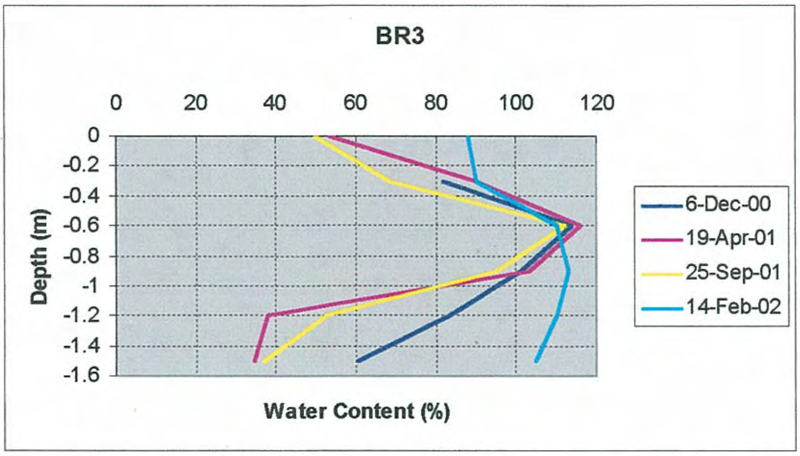

Figure 6.7(c) Subgrade water content profile - Pit BR3.

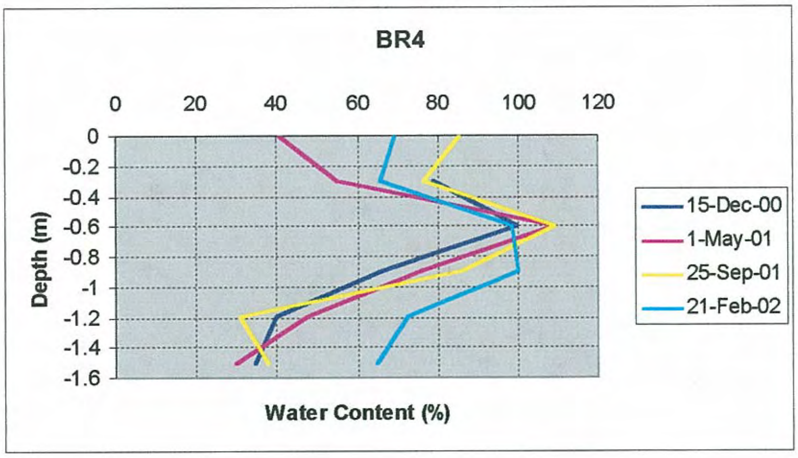

Figure 6.7(d) Subgrade water content profile - Pit BR4.

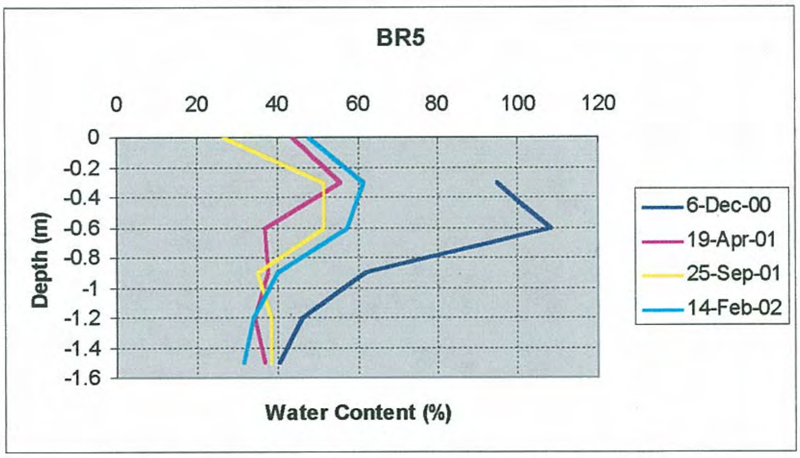

Figure 6.7(e) Subgrade water content profile - Pit BR5.

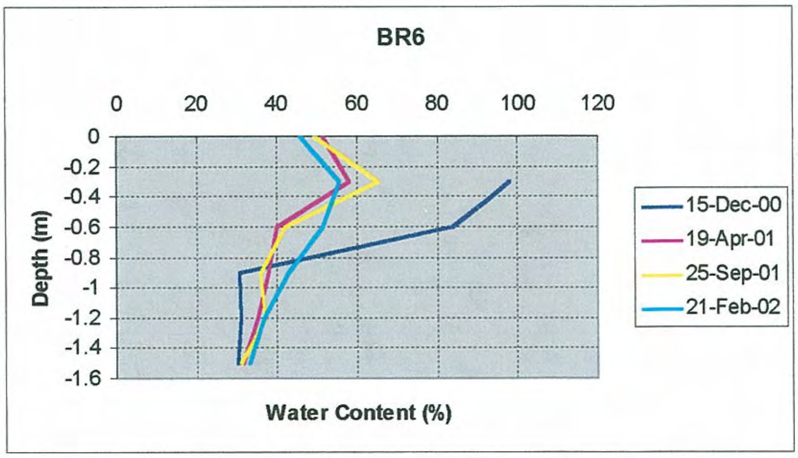

Figure 6.7(f) Subgrade water content profile - Pit BR6.

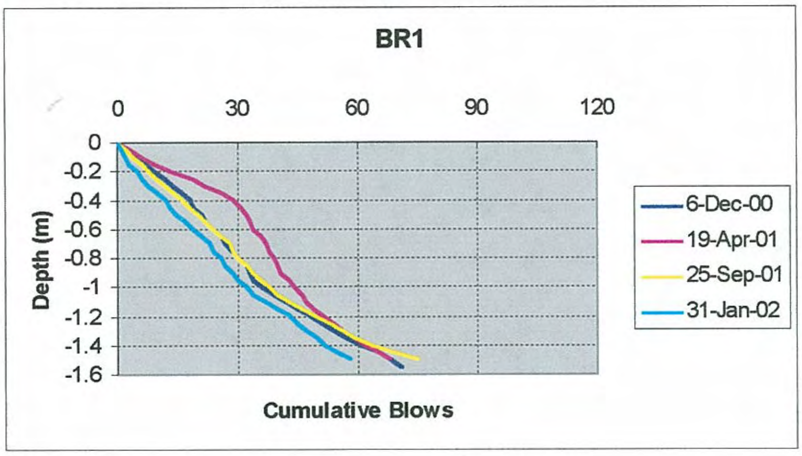

Figure 6.8(a) Subgrade DCP cumulative blows versus depth - Pit BR1.

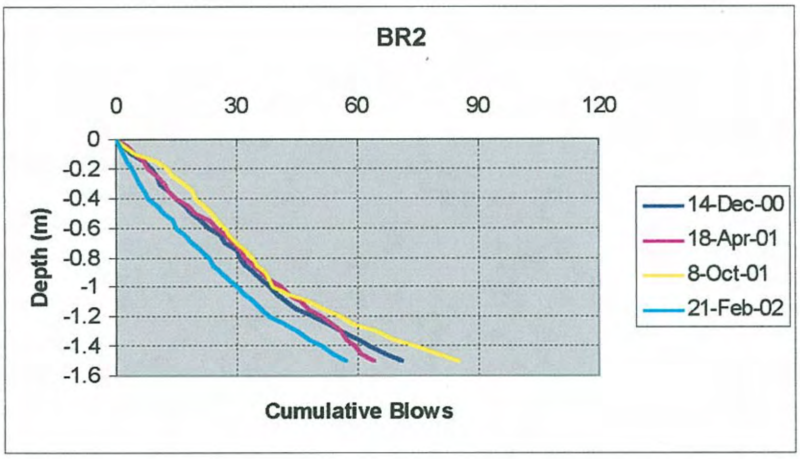

Figure 6.8(b) Subgrade DCP cumulative blows versus depth - Pit BR2.

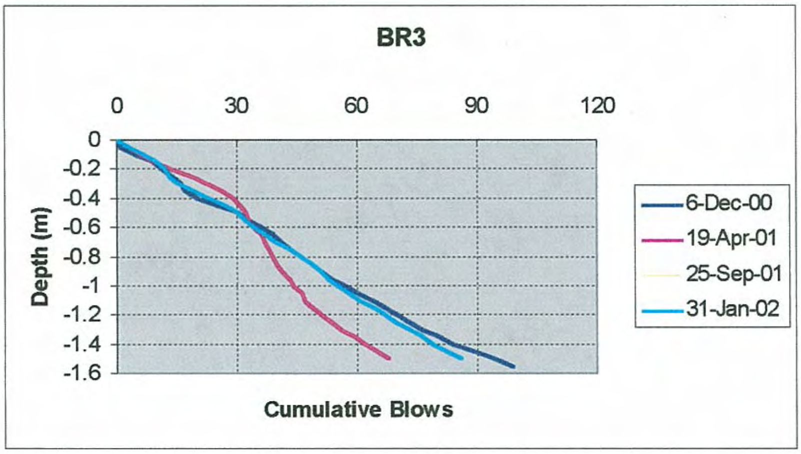

Figure 6.8(c) Subgrade DCP cumulative blows versus depth - Pit BR3.

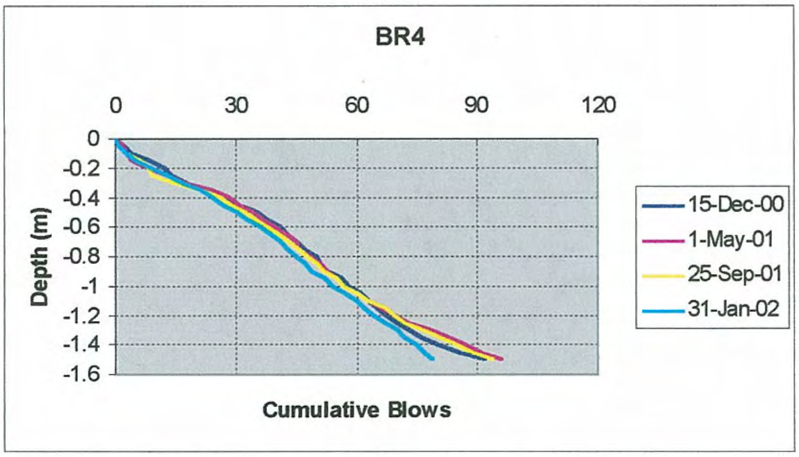

Figure 6.8(d) Subgrade DCP cumulative blows versus depth - Pit BR4.

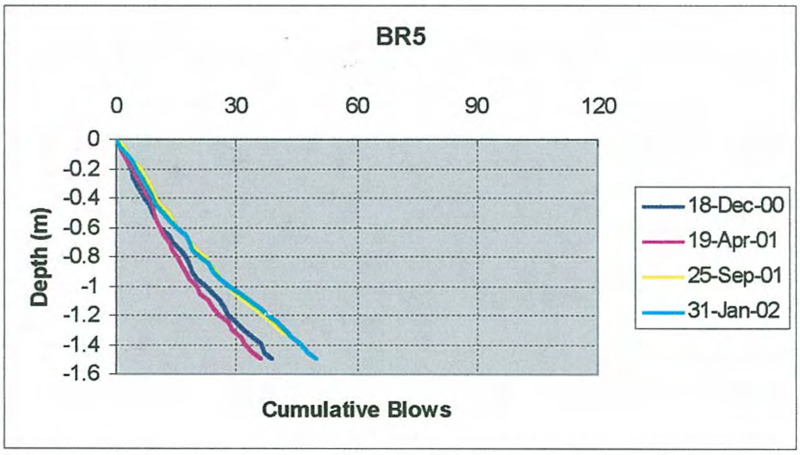

Figure 6.8(e) Subgrade DCP cumulative blows versus depth - Pit BR5.

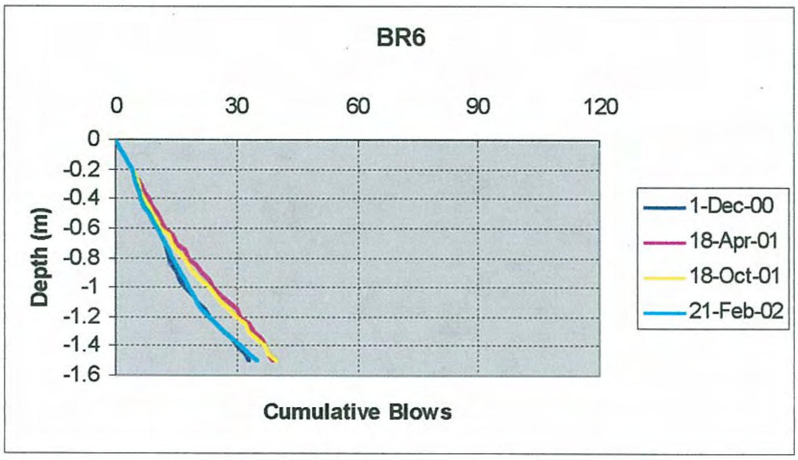

Figure 6.8(f) Subgrade DCP cumulative blows versus depth - Pit BR6.

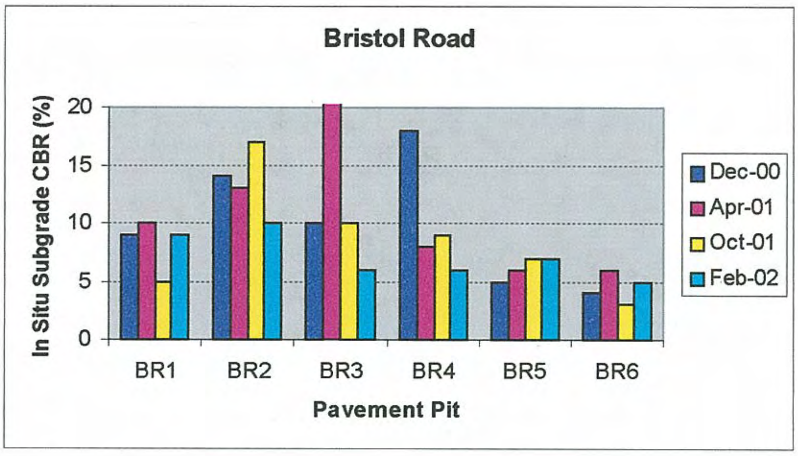

Figure 6.9 In situ subgrade CBR for each round of testing, at Bristol Road.

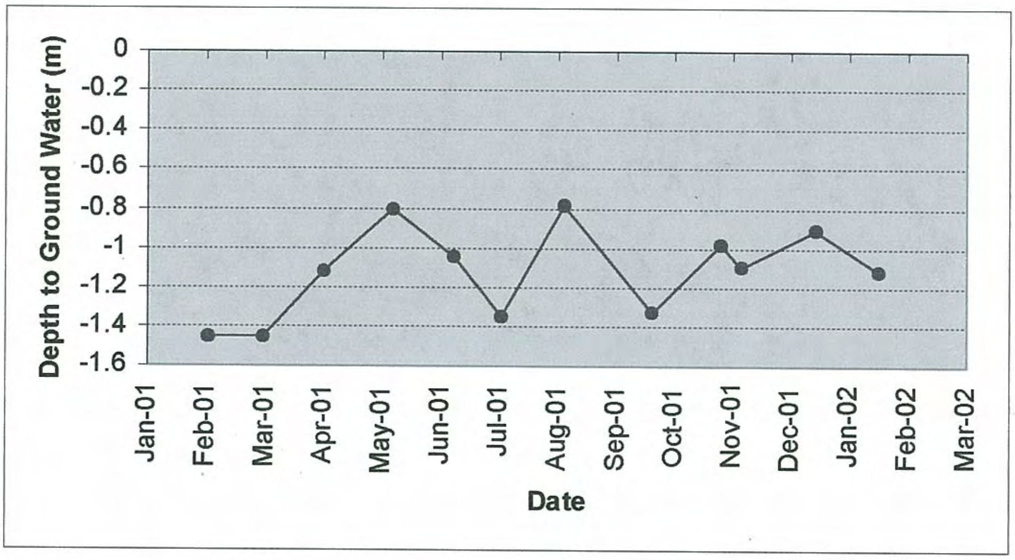

Figure 6.10 Depth to ground water (from pavement surface) versus time (from 1/01 to 1/02) for BR3.

6.3.6 Ground-water Level Measurements

A standpipe was installed at BR3 to a depth of 1.76 m below the surface of the pavement and it was dipped on a monthly basis from February 2001 until February 2002. The ground-water level results are plotted in Figure 6.10.

6.4 Atterberg Limits

Atterberg Limit tests were carried out at each test location and each subgrade soil type as part of the first round of testing. A plot of Liquid Limit and Plastic Limit versus water content (for all four rounds of testing) is shown in Figure 6.11.

The data in Figure 6.11 indicate that most of the subgrade soil specimens were at water contents equal to or slightly above their Plastic Limits. This may represent an equilibrium water content condition given that the pavements in question have been in service for many years.

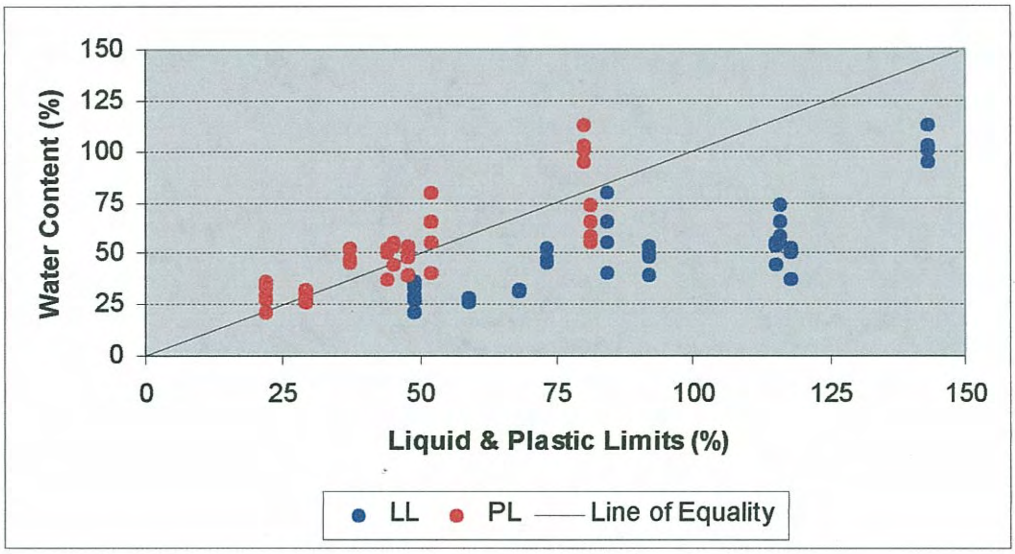

Figure 6.11 Liquid and Plastic Limits versus water contents.

7. Analysis of the Results

7.1 Introduction

To analyse the test data, rainfall records from meteorological observation stations (listed in Table 7.1) nearest to the test sections were obtained.

Table 7.1 Meteorological stations nearest to the test sections.

Test Section	Nearest Meteorological Observation Station
Kohimarama Road	Pakuranga
Blockhouse Bay Road	Henderson
Bristol Road	Henderson

Figure 7.1 shows the rainfall records for the Pakuranga and Henderson meteorological observation stations for the duration of the research period, along with the historical mean monthly rainfall (supplied by Metgen Meteorological Consultancy Ltd) for the Auckland area. Figure 7.1 does not show any strong seasonal trend in the rainfall records over that period.

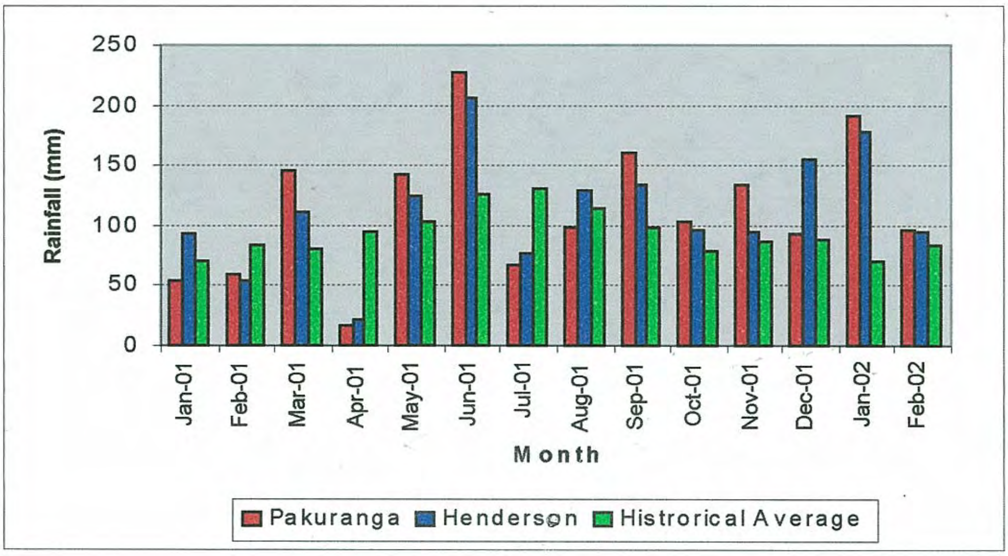

Figure 7.1 Rainfall data for the research period (1/01-2/02), obtained from two meteorological observation stations nearest the test sections.

The analysis of the test data is based on the following main relationships:

- ground-water level to rainfall;
- soil water content to rainfall and transverse location in the pavement;
- DCP to water content;

- in situ CBR to the ground-water level and/or rainfall;
- in situ CBR to inferred CBR from DCP;
- in situ CBR and inferred dynamic cone CBR to soaked CBR; and
- in situ water content to soaked specimen water content.

7.2 Ground-water Level in Relation to Rainfall

Standpipes were installed to a depth of approximately 1.8 m at all three test sites and the ground-water level was measured on a monthly basis from January 2001 to February 2002. The records for the Kohimarama Road and Blockhouse Bay Road test sections showed that the standpipes remained dry for the entire period of the monitoring. The ground-water level records for the Bristol Road site are presented in Figure 7.2, which also shows the monthly rainfall records for the Henderson meteorological observation site.

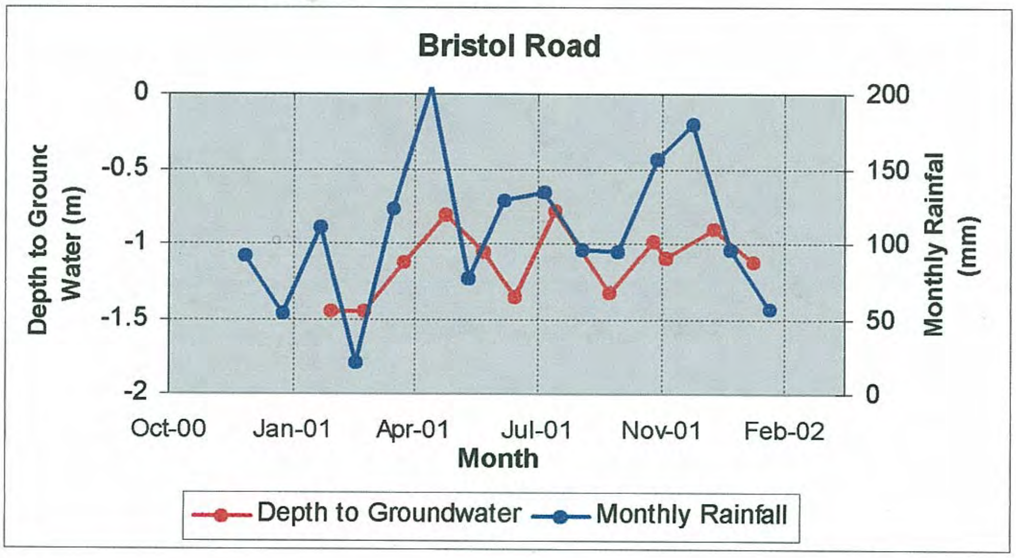

Figure 7.2 **Depth to the ground-water level, and corresponding monthly rainfall records from Henderson meteorological station, over the period of monitoring (1/01- 2/02) .**

Figure 7.2 shows that the depth to ground water follows the monthly rainfall, albeit with a delay of a few weeks. This is a reasonable result given that:

- the general area of the pavement is relatively flat and low-lying;
- the standpipe was located in the left wheel track (i.e. quite close to the edge of the pavement);
- surface water run-off was not managed by kerbing and channelling; and
- the berms adjacent to the carriageway were grassed.

The combination of these factors means that rainfall influenced the ground-water level and the influence was detected under the left wheel track of the carriageway.

7.3 Soil Water Content in Relation to Rainfall & Pavement Location

7.3.1 General

The soil water content is dependent on a number of factors including the soil type, the soil particle size distribution, the level of the ground-water table, the nature of the adjacent materials, etc. Therefore, the water content data cannot be used in a general manner, although changes in water content throughout the monitoring period can be considered.

To examine the effect of rainfall on the subgrade water content, see the plots of water content versus depth (Figure 6.1(a-f) for Kohimarama Road, Figure 6.4(a-f) for Blockhouse Bay Road, and Figure 6.7(a-f) for Bristol Road), and the corresponding rainfall records (Figure 7.1).

7.3.2 Kohimarama Road

The plots of subgrade water content versus depth for Kohimarama Road (Figure 6.1 (a–f)) show that the subgrade water contents are reasonably consistent for all four rounds of testing. The exception is for February 2002, results of which are typically lower than the other results for at least part of the subgrade profile, KO4 excluded. In addition, the results for the lower portion of the subgrade at KO2 show that the April 2001 water contents are somewhat lower than for the other tests.

The rainfall data for the Pakuranga meteorological observation site (Figure 7.1) shows that the February 2001 rainfall was relatively low, but not to the extent that it would be expected to have a significant influence on the soil water content data. The March 2001 rainfall was very low, which may explain why the KO2 water contents for the April 2001 tests are relatively low, although the same trend was not observed at the other pavement pits.

With pavement pits KO2, KO4 and KO6 located under the centre of the carriageway, the resulting water contents would be expected to be more consistent than the data obtained for pavement pits KO1, KO3 and KO4 which were located under the left wheel track. This trend was not observed however, but the berm on the western side of the carriageway, i.e. on the side adjacent to the left wheel track tests, was surfaced in concrete and asphalt, and it would be relatively impermeable, thus influencing the water content.

7.3.3 Blockhouse Bay Road

The plots of subgrade water content versus depth for Blockhouse Bay Road (Figure 6.4(a-f)) show that the subgrade water contents range from very consistent (e.g. BB1) to very inconsistent (e.g. BB4) for the four rounds of testing.

Although clear trends do not emerge, the most variable test location, BB4, shows the February 2001 test result to be significantly drier than the other tests at that location. This is similar to the result found for the Kohimarama Road test section. The rainfall record for the Henderson meteorological observation site (Figure 7.1) shows that the rainfall was not significantly lower for January or February 2002. Also the low rainfall measured in March 2001 is not reflected in the water content data for the April/May 2001 round of testing.

No clear trend of improved consistency is recorded for the tests located at the centre of the carriageway (BB2, BB4 and BB6) in comparison to those located under the left wheel track (BB1, BB3 and BB5).

7.3.4 Bristol Road

The plots of subgrade water content versus depth for Bristol Road (Figure 6.7(a-f)) show that the subgrade water content profiles range from being reasonably consistent (e.g. BR1) to very inconsistent (e.g. BR2) for the four rounds of testing.

At test locations BR2, BR5 and BR6, the December 2000 test results are the most disparate, with the upper subgrade materials being relatively dry at BR2 and relatively wet at BR5 and BR6. In addition, the February 2002 results at the lower levels of the BR3 and BR4 subgrades are significantly wetter than for the other three rounds of testing. These trends are difficult to resolve with respect to the Henderson rainfall records (Figure 7.1).

As for the other test sections, no significant trends were seen in the water content responses located under the left wheel track in comparison with those located at the centre of the carriageway.

7.4 Dynamic Cone Penetration in Relation to Water Content

7.4.1 General

As for the subgrade water content data, the DCP data are most conveniently analysed by viewing them in conjunction with the water content profiles at each test location. The DCP profiles are presented in Figure 6.2(a-f) for Kohimarama Road, Figure 6.5(a-f) for Blockhouse Bay Road, and Figure 6.8(a-f) for Bristol Road.

7.4.2 Kohimarama Road

The DCP profiles for the successive rounds of testing at Kohimarama Road are presented in Figures 6.2(a-f). The plots show cumulative DCP blows versus depth below the surface of the subgrade.

The DCP profiles indicate that the November/December 2000 and the October 2001 testing rounds produced the greatest subgrade strength/stiffness with respect to DCP resistance. In particular, the October 2001 test results were significantly greater than the other results at KO1 and KO4 (Figures 6.2(a) and 6.2(d)). However, the corresponding water content profiles (Figures 6.1(a) and 6.1(d)) showed that the respective water contents were comparable to the results of the other rounds of testing. Similarly, at locations KO3 and KO6 where the November/December 2000 tests produced the greatest DCP resistance (Figures 6.2(c) and 6.2(f)), the corresponding water content profiles (Figures 6.1(c) and 6.1(f)) were comparable to the results of the other rounds of testing.

Of the four rounds of test results, the February 2002 DCP profiles produced the least, or second least, DCP resistance. However, the February 2002 water content profiles generally showed the lowest water content results. This is contrary to what would generally be expected.

7.4.3 Blockhouse Bay Road

The DCP profiles for successive rounds of testing at Blockhouse Bay Road are presented in Figure 6.5 (a-f). The plots show cumulative DCP blows versus depth into the subgrade.

The greatest DCP resistance was typically found for the November/December 2000 and/or the October 2001 rounds of testing. In particular, the November/December 2000 profiles showed the greatest DCP resistance at BB1, BB2 and BB5 (Figure 6.5(a), 6.5(b) and 6.5(e)). The corresponding subgrade water content profiles (Figures 6.4(a), 6.4(b) and 6.4(e)) show that the water content profiles in question do not have any clear trends of dissimilarity from the results of the other rounds of testing. A similar scenario of high DCP resistance with no apparent relationship with the corresponding water content profiles occurred for the October 2001 round of testing at BB4 and BB6.

7.4.4 Bristol Road

The DCP profiles for successive rounds of testing at Bristol Road are presented in Figure 6.8(a-f). The plots show cumulative DCP blows versus depth into the subgrade.

The Bristol Road DCP profiles were the most consistent of the three test sections throughout the four rounds of testing. There is an indication of increased DCP resistance for the April 2001 round of tests in the upper portion of the profile at BR1 (Figure 6.8(a)). However, this trend does not follow for the other pavement pit locations, nor is there any apparent correlation in the water content profile for BR1 (Figure 6.7(a)).

7.5 In Situ CBR in Relation to Ground-water Level & Rainfall

7.5.1 Kohimarama Road

The in situ CBR results for each pavement pit and each round of testing at the Kohimarama Road test section are presented in Figure 6.3. The data show no clear trends with the possible exception that the December 2000 and/or the April 2001 tests generally produced the highest CBR responses. Two inexplicably high CBR responses were obtained at KO3 and KO6 in the December 2000 round of testing.

The relatively low rainfalls measured in December 2000 and March 2001 may be linked with the generally higher in situ CBR results obtained in the December 2000 and the April 2001 rounds of testing. The relatively low in situ CBR results obtained for the February 2002 round of testing cannot be correlated to significantly higher rainfall measurements for the corresponding period.

7.5.2 Blockhouse Bay Road

The in situ CBR results for each pavement pit and each round of testing at the Blockhouse Bay Road test section are presented in Figure 6.6. The CBR values are relatively low and do not show clear trends for the four rounds of testing.

7.5.3 Bristol Road

The in situ CBR results for each pavement pit and each round of testing at the Bristol Road test section are presented in Figure 6.9. The data shows no clear trends for the four rounds of testing.

7.6 In Situ CBR in Relation to DCP-Inferred CBR

The test programme allows a comparison of the subgrade CBR values determined from the in situ test procedure and the values inferred from the DCP. Figure 7.3 shows a plot of DCP-inferred subgrade CBR, as the mean value for the upper 100 mm of subgrade, versus in situ CBR for each of the three test sections.

Figure 7.3 shows a reasonable correlation between the DCP-inferred CBR and the in situ CBR values. The R^2 value for the raw data is 0.56.

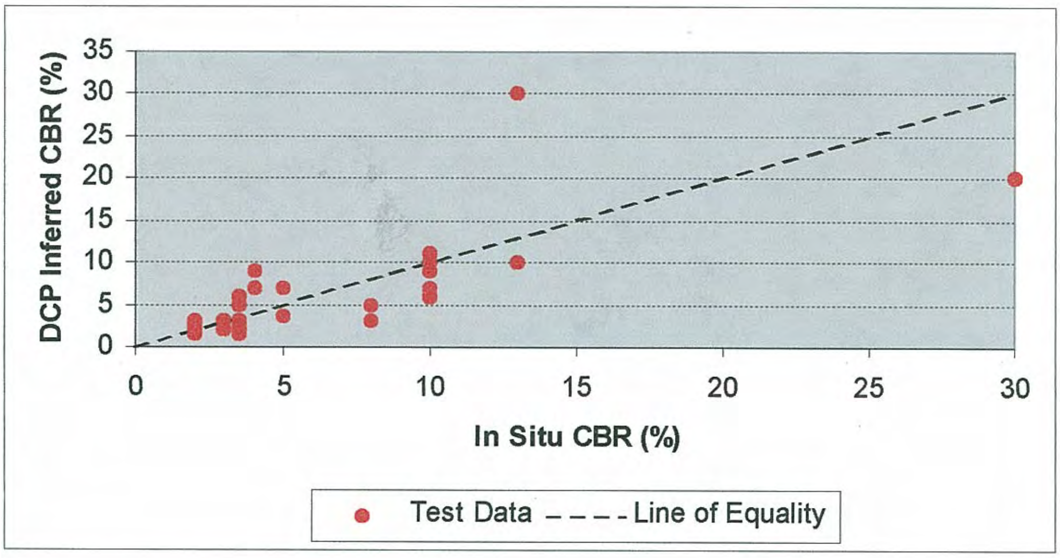

Figure 7.3 DCP-inferred CBR versus in situ subgrade CBR results.

7.7 In Situ & DCP-Inferred CBR in Relation to Laboratory Soaked CBR

Laboratory soaked CBR tests were carried out using samples of subgrade soil recovered from the top 200 mm of the subgrade at each of the left wheel track test pit locations, i.e. KO1, KO3, KO5, BB1, BB3, BB5, BR1, BR3 and BR5.

The laboratory CBR tests represent the typical site investigation process for which remoulded specimens prepared at field water content are used and subsequently soaked for four days before testing. The tests were carried out in June 2002 after a period of relatively wet weather. Figure 7.4 (a–c) presents the results of the in situ and DCP-inferred subgrade CBR tests, along with the corresponding laboratory CBR test results for each test section.

The Kohimarama Road test results (Figure 7.4(a)) indicate that the laboratory CBR values show a reasonable correlation with the in situ CBR test results at pits KO1 and KO3. However, the laboratory CBR values are conservative compared with the in situ CBR results at pit KO5, and with all of the DCP-inferred CBR results, especially at pit KO5.

The Blockhouse Bay Road test results (Figure 7.4(b)) indicate that the laboratory CBR results correlate well with both the DCP-inferred CBR and the in situ CBR results.

The Bristol Road test results (Figure 7.4(c)) indicate an inconsistent response with respect to the in situ and laboratory CBR tests. A reasonable correlation is obtained for both in situ tests and the laboratory CBR tests at pit BR3. However, the data for Pit BR1 show that the laboratory CBR correlates well with the in situ CBR results but somewhat overstates the strength with respect to the DCP-inferred CBR. At pit BR5 the laboratory CBR is overly conservative with respect to both the in situ and DCP-inferred CBR results.

The test data presented in Figure 7.4(a-c) provide reasonable evidence that the soaked CBR parameter would characterise the subgrade condition at Kohimarama Road in an overly conservative manner. However the soaked CBR parameter would characterise the subgrade conditions at Blockhouse Bay Road and Bristol Road (with the exception of BR5) with acceptable accuracy.

7.8 In Situ Water Content in Relation to Laboratory CBR Specimen Water Content

The water contents of the laboratory CBR specimens were determined before and after the four-day soaking period. Table 7.2 presents the initial and final water contents for each of the laboratory CBR specimens.

These data show that, in general, the CBR test specimen water contents did not change greatly as a result of soaking and in many instances the change in water content would be within the margin of error of the measurement. This suggests that either the soils were relatively impermeable, or the soils were close to saturation pre-soaking.

A comparison of the water contents of the subgrade soils taken from the upper 200 mm of the test pits during each round of field testing and the water content of the soaked CBR specimens was made, and the results are presented in Figure 7.5.

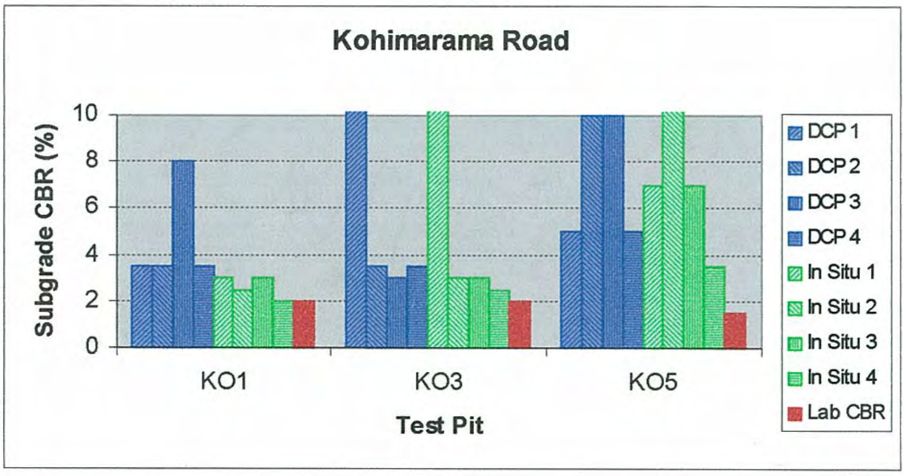

Figure 7.4(a) DCP, in situ and laboratory (soaked) subgrade CBR results for the left wheel track test pits at the Kohimarama Road test section.

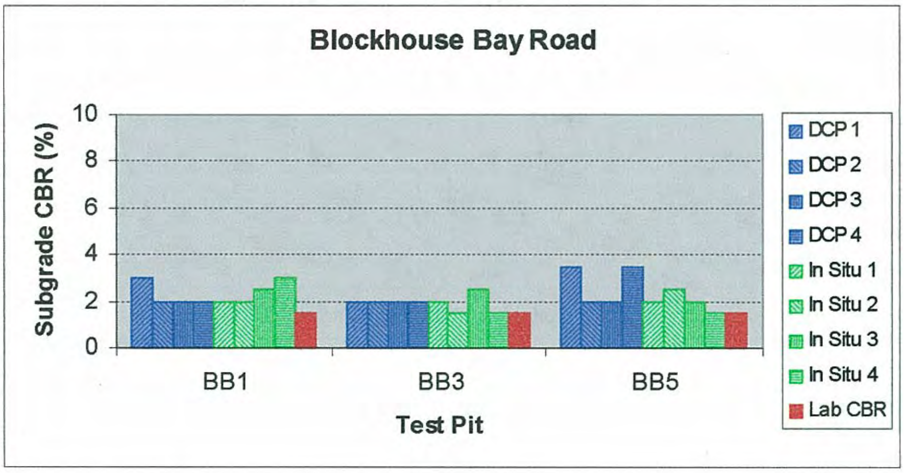

Figure 7.4(b) DCP, in situ and laboratory (soaked) subgrade CBR results for the left wheel track test pits at the Blockhouse Bay Road test section.

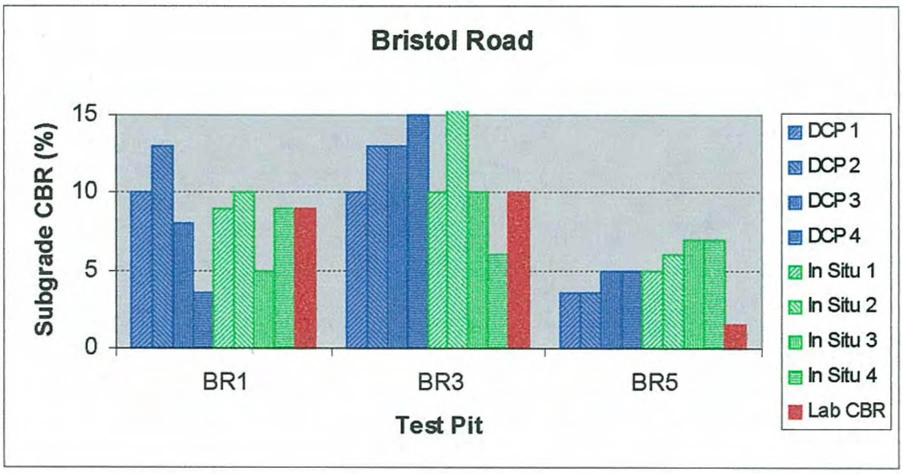

Figure 7.4(c) DCP, in situ and laboratory (soaked) subgrade CBR results for the left wheel track test pits at the Bristol Road test section.

Table 7.2 Pre- and post-soaking water contents for the laboratory CBR specimens.

Pit	Pre-soaking Water Content (%)	Post-soaking Water Content (%)
KO1	32.6	33.1
KO3	19.4	19.8
KO5	20.6	21.1
BB1	34.7	37.6
BB3	48.7	51.1
BB5	49.4	50.2
BR1	71.4	73.2
BR3	54.2	60.3
BR5	53.3	55.4

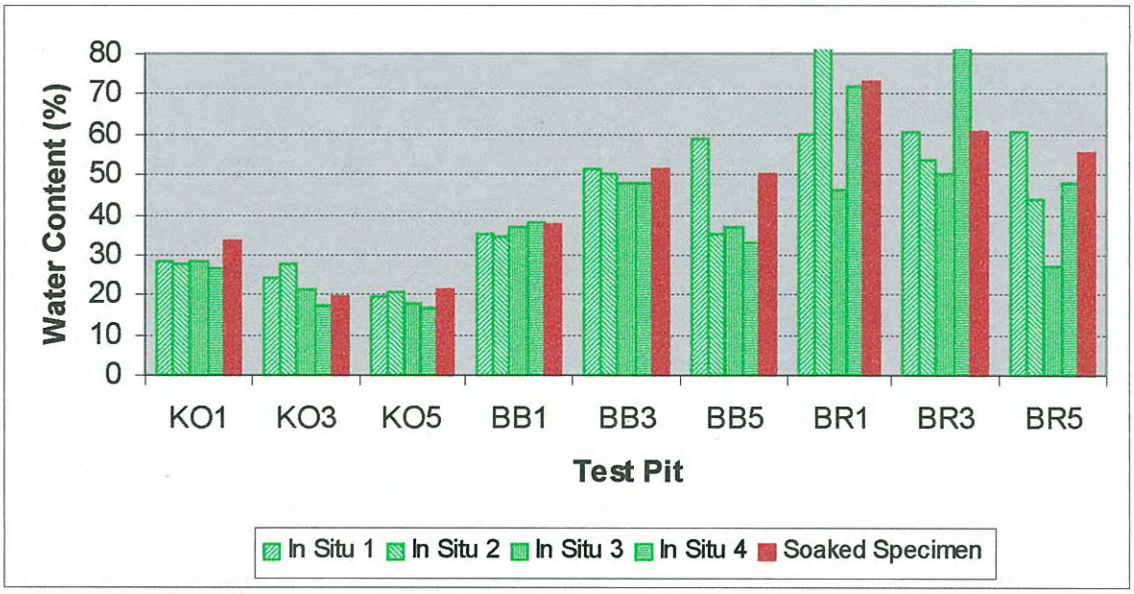

Figure 7.5 Plot of in-situ and soaked CBR specimen water contents.

The data presented in Figure 7.5 indicate that the water contents of the laboratory soaked CBR specimens characterise the water contents of the field conditions reasonably well. The only exceptions are the soils at pits KO1, and possibly BB5, where the soaked specimen water contents are higher than the in situ water contents.

7.9 Interpretation

The test data show no apparent relationship between the rainfall records and the water content of the subgrade soils at the three sites monitored in this research. In addition, no relationship was apparent between the soil water content and the soil strength/stiffness as determined using both the DCP and the in situ CBR test procedures. This may be attributable to the soil types encountered, their variability within short horizontal distances, and/or the accuracy of the testing procedures, in terms of both inherent inaccuracies and operator consistency.

A reasonable correlation was identified between the monthly rainfall records and the depth to the ground-water level at the Bristol Road test section. The ground-water level was not reached within approximately 1.8 m of the pavement surface at the Kohimarama Road or Blockhouse Bay Road test sections.

The in situ CBR and the DCP profile through the top 100 mm of subgrade showed a relatively good relationship. This observation validates the DCP to CBR correlation presented in AUSTROADS (1992), at least for the conditions encountered at the test sections. It also suggests that the depth of influence of the in situ CBR test equipment is relatively shallow, i.e. of the order of 100 mm.

When examining the meaning of the laboratory CBR tests, the physical significance of the soaking process is worth considering. Placing a CBR test specimen in a water bath to achieve a soaked condition is akin to a 'real' subgrade having excess water available to be taken up by the soil. This is comparable to the subgrade being inundated or below the ground-water level. The soil can be in a saturated or unsaturated condition either before or after soaking takes place, depending on a number of factors including the specimen permeability, saturation ratio and soil mineralogy.

Comparing the field CBR tests (both in situ CBR and DCP-inferred CBR) at various times of the year with the laboratory CBR tests gives an indication of the appropriateness of characterising the subgrade using soaked specimens. The water contents measured in the soaked test specimens correspond reasonably well with the water contents measured in the field at the Blockhouse Bay Road and Bristol Road sites. However, the water contents of the soaked specimens for Kohimarima Road (KO1 and KO5) were slightly higher than the corresponding field measurements. This trend was confirmed with respect to the in situ and laboratory CBR test results. The soaked CBR values for Kohimarama Road were consistently lower than both the in situ and DCP-inferred CBR values. This suggests that designing on the soaked CBR would be overly conservative for the Kohimarama Road site. Conversely, the soaked CBR tests appeared to characterise the field subgrade conditions reasonably well for the Blockhouse Bay and Bristol Road sites.

The test results are consistent with the researcher's initial impressions that the subgrade at Kohimarama Road would be best characterised in a condition other than soaked. By inspection, quite clearly the topography of the site means that the ground-water level would be some distance below the top of the subgrade, that incidental rain water is well managed and infiltration from adjacent ground would be minimal. The standpipe installed at the site confirmed that the ground-water level was greater than 1.8 m from the pavement surface throughout the monitoring period.

The topography of the Blockhouse Bay Road and Bristol Road sites suggested that the ground-water level could be reasonably shallow, and this was confirmed by the standpipe measurements at Bristol Road. While the standpipe at Blockhouse Bay Road was dry for each reading, an inspection of the site would suggest that the ground-water regime would be intermediate between the relatively dry conditions at Kohimarama Road and the relatively wet conditions at Bristol Road.

An important aspect of the research was that no significant seasonal trend was observed in the test data, including the monthly rainfall records. Comparison of the rainfall data with the historical monthly average rainfall confirmed that the testing period was somewhat atypical in this regard, although it does raise the issue that testing carried out in summer months may not be as non-conservative as some designers might think.

The transverse location of the testing did not appear to influence the results, i.e. there was no distinction between the left wheel track and centreline test data. The expected increased uniformity of conditions under the centreline of the pavement was not observed for the selected locations.

8. Proposed Design Subgrade Characterisation

The lack of correlation between various fundamental soil and rainfall parameters in this research calls into question many of the current processes for determining DMC and design subgrade CBR (or elastic modulus) presented in Chapter 4 of this report.

Despite this, the AUSTROADS subgrade characterisation procedures should be followed for major pavement projects. However, for most routine pavement designs, the designer simply needs to decide if the subgrade should be characterised in a soaked or an unsoaked condition, and to decide on the moisture condition for test specimen preparation. Generally neither the time nor budget is available to perform the number of tests or to monitor for seasonal variations as recommended in the AUSTROADS design procedures (see Section 4.3 of this report, and AUSTROADS 1992).

Instead, a simplified procedure could be followed based on the literature review and the field testing carried out in this project. As the test data were obtained over a very limited time period and at a limited number of sites, further investigations should be carried out to substantiate and/or amend the proposed approach.

8.1 Soaked or Unsoaked Soil Test Conditions

The question of soaked or unsoaked soil test conditions is dictated by the expected in-service subgrade moisture. The proposal is that:

- if the ground-water level is likely to be within one metre of the top of the subgrade for a significant period of time, and/or on a repeated basis, soaked subgrade strength/stiffness parameters are appropriate;
- if the ground-water level is likely to remain below one metre of the top of the subgrade, unsoaked parameters are considered to give appropriate reasonable results.

Factors that can have a significant influence on the level of the ground water are described in Table 8.1, and the designer should consider these issues before deciding whether to use soaked or unsoaked subgrade strength/stiffness parameters.

8.2 Preparation of Test Specimens

The expected moisture conditions at the time of construction dictate the appropriate conditions for the preparation of test specimens. These moisture conditions will be influenced by the degree of control the designer has on the construction.

For example, in green-fields developments in cut or at-grade situations, or in the rehabilitation of existing pavements, if the designer has little control on the moisture conditions in the upper one metre of subgrade soil, especially in fine-grained soils, test specimens should be prepared at natural water content. The natural water content is determined as that at a level below any near-surface influences, and taking into consideration any seasonal effect. The test specimen dry density should correspond with the in situ dry density. Alternatively, undisturbed specimens could be recovered for subsequent testing.

Table 8.1 Effects of factors influencing subgrade moisture parameters and ground-water levels.

Factor	Effects on subgrade moisture conditions
Topography	The topographical setting of the pavement has a strong bearing on the potential for the ground-water level. If ground-water level lies within 1 m of top of subgrade, use soaked soil conditions. If ground-water level lies below 1 m of top of subgrade, use unsoaked soil conditions, e.g. pavements founded on embankments should generally be characterised with unsoaked soil conditions.
Inundation potential	If the potential for a pavement is to become inundated for a reasonable period of time and/or on a regular basis, use only soaked subgrade parameters.
Drainage	Drainage provisions such as subsoil and side drains should be considered for their ability to influence the ground-water level, primarily by stopping water from entering the pavement. The ongoing efficacy of the drains may be questionable and need to be maintained.
Soil type	Subgrade soil type and permeability influence the moisture regime, e.g. capillary action in some soil subgrades may cause saturation.
Rainfall - quantity	On a flat or near-flat site, the higher the rainfall the higher the ground-water level is likely to rise. Rainfall records should be used as a secondary criterion to determine if soaked or unsoaked parameters are appropriate.
- seasonality	Records can also be used to determine if seasonal variation is a significant issue. If so, investigations should be carried out during the wettest season, or appropriate allowances should be made when testing is carried out in a drier period.
Shoulder / berm conditions	Permeable shoulders and berms can feed water into the pavement subgrade and, if pavement drains are not provided, the ground-water level may rise to such a degree that soaked subgrade parameters are appropriate.

If the designer has a greater degree of moisture control, as in a (green-fields) fill situation, test specimens should be prepared at the water content and dry density required in the construction specification. This should preferably be a condition slightly on the wet side of optimum water content. The proposed subgrade characterisation conditions are summarised in Table 8.2.

Table 8.2 Summary of proposed subgrade characterisation conditions.

In-service Condition	Subgrade Configuration	Test Condition	Test Specimen Condition
Ground-water level potentially in upper 1 m of subgrade	Fill	Soaked	Water content as per construction specification, corresponding dry density from compaction test.
	Cut / At Grade	Soaked	Water content & dry density as per natural conditions, considering near-surface influences & seasonal effects. Alternatively use undisturbed samples.
Ground-water level below upper 1 m of subgrade	Fill	Unsoaked	Water content as per construction specification, corresponding dry density from compaction test.
	Cut / At Grade	Unsoaked	Water content & dry density as per natural conditions considering near-surface influences & seasonal effects. Alternatively use undisturbed samples.
Ground-water level unknown; Water content unknown; Additional reliability required		Soaked	Judgement required as well.

Additional testing should be carried out using a greater range of pavement sites where the influence of the factors described in Table 8.1 can be investigated further. A more automated approach (using time domain reflectometers or similar) would be desirable so that continued destructive testing is not required.

9. Conclusions

This report presents the results of:

- a literature review on the topic of characterising subgrade moisture conditions for pavement design,
- a field investigation aimed at determining seasonal changes in subgrade moisture conditions, and
- the resulting effects on subgrade performance.

Three test pavement sections around the Auckland Region were selected for the field investigation. At each test section, three pairs of test locations (left wheel track and pavement centreline) were subjected to water content, DCP, standpipe water level, and in situ CBR tests. Atterberg Limit tests were also carried out to characterise the subgrade soils which generally comprised clayey silts and silty clays. The tests were carried out first in December 2000, and they were repeated on three further occasions (April 2001, October 2001, and February 2002). In June 2002, subgrade samples were recovered from each test section for laboratory soaked CBR tests.

Relationships between subgrade moisture content and test parameters

- One conclusion of the field testing is that very few relationships were determined between the various parameters that were measured. An exception was the reasonable correlation between the ground-water level and the rainfall record for the corresponding month for the Bristol Road test section. Standpipes installed at the other two test sites did not record any ground water within 1.8 m of the pavement surface.

- No relationships were apparent between either the subgrade water content tests and the rainfall records, or the water content and DCP test results. In addition, the transverse location of the tests (left wheel track or carriageway centreline) appeared to have no influence on the test results. Typically, the soil water contents were at or slightly above the Plastic Limit.

- A reasonable relationship was found between the in situ CBR and the DCP-inferred CBR results (averaged over the upper 100 mm of subgrade). This provides some degree of validation for the DCP blow count to CBR relationship presented in AUSTROADS (1992), at least for the subgrade conditions prevailing at the test sections.

- The soaked laboratory specimens characterised the in situ water content and CBR parameters reasonably well for the Blockhouse Bay Road and Bristol Road test sections. However the soaked specimens were somewhat conservative for both water content and CBR at the Kohimarama Road test section. This result was consistent with the expectations of the researchers given the topography and ground conditions surrounding the Kohimarama Road site.

- Clear conclusions regarding the most appropriate means of characterising subgrade soil conditions for pavement design were difficult to derive, given the lack of data correlations from the field investigation.

  Irrespective of this, a simple procedure for routine design applications has been proposed:

  - to provide guidance regarding test specimen preparation according to:
  - construction conditions, i.e. cut, fill or at-grade,
  - green-field development, or
  - rehabilitation of an existing pavement.
  - To determine whether soaked or unsoaked subgrade conditions are appropriate for test specimens used for characterising in-service subgrade soil conditions.

Procedure for Subgrade Characterisation

The procedure for characterisation of subgrade water content, using test specimens prepared according to NZS 4402 Test 2.1, is based on an evaluation of the ground-water level as follows:

- If ground-water level is likely to rise into the upper one metre of the subgrade for any significant period of time or repeatedly, then soaked test specimens are appropriate.

- If the ground-water level is most likely to stay below the upper one metre of the surface of the subgrade, then unsoaked test specimens are appropriate.

- If ground-water level is at uncertain or unknown depth, or the subgrade moisture regime may be in doubt, or where an additional degree of reliability is deemed to be appropriate, then soaked parameters should be used.

- For cut or at grade construction conditions,
  - prepare specimens at natural water content. Carry out tests under soaked or unsoaked conditions according to likely location of ground-water level.

- In fill construction conditions,
  - prepare specimens at construction specification moisture content. Carry out tests under soaked or unsoaked conditions according to likely location of ground-water level.

Recommendation

The procedure has been by no means exhaustively tested and the recommendation is that additional research is carried out to examine the influence of the above factors in further detail.

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NZ Standards

NZS 4402 Methods of testing soils for civil engineering purposes.
(in numerical order of the tests)

1986: Test 2.1 Soil classification test. Determination of the water content.

1986: Test 2.2 Soil classification test. Determination of the liquid limit.

1986: Test 5.1.4 Soil density tests. Determination of the density of soil: Immersion in water method.

1988: Test 6.1.1 Soil strength tests. Determination of the California Bearing Ratio (CBR): Standard laboratory method for remoulded specimens.

1986: Test 6.1.3 Soil strength tests. Determination of the California Bearing Ratio (CBR): Standard laboratory method for in situ tests.

1988: Test 6.5.2 Determination of the penetration resistance of a soil: Hand method using a dynamic cone penetrometer.

NZS 4407 Part 3 - Methods of testing road aggregates - Laboratory tests.

1991: Test 3.15 The Californian Bearing Ratio (CBR).

Glossary

Aggregate	A general term for mineral particles such as crushed rock, slag, gravel and sand.
AASHTO, previously **AASHO**	Association of American State Highway & Transportation Officials, previously Association of American State Highway Officials.
ARRB	Australian Road Research Board.
Atterberg Limits Test	This test method describes the measurement of: *Liquid Limit, Plastic Limit, Shrinkage Limit* - which define the water contents of the soil at the upper and lower boundaries of the plastic state respectively. *Shrinkage Limit* - the water content of the soil below the *Plastic Limit* when no further shrinkage will take place. *Plasticity Index* - the numerical difference between *Liquid* and *Plastic Limits.*
AUSTROADS	National Association of Road Transport & Traffic Authorities in Australia.
Basecourse	The layer of material constituting the uppermost structural element of a pavement, immediately beneath the wearing course. The graded aggregate that can be used in such a layer.
Benkelman Beam	Instrument for measuring deflections of a pavement under load.
Binder	A general term for a material used to hold aggregates in place.
Bitumen	A viscous liquid or solid obtained by processing the residue from the distillation of suitable crude petroleum.
CBR	California Bearing Ratio, test for strength of soil (NZS 4402: 1986 Test 6.1.1; NZS 4407: 1991 Test 3.15).
Compaction - NZS Standard	Compaction of a soil sample in accordance with NZS 4402: 1986.
CMC	See *Compaction moisture content.*
MCS	Minimum compaction standard.
Density	Mass per unit volume of a material.
Bulk Density	Mass per unit volume of a material including solid particles, water and voids contained in it.
Dry Density	Mass of dry material in unit volume of a soil sample after drying at 105 °C.
MDD	Maximum dry density.
Design Moisture Content (DMC)	Moisture content used when designing the subgrade for a road. See *Moisture Content.*

Durability	The ability of a material to continue to provide the service for which it is intended.
Dynamic Cone Penetrometer (DCP)	Instrument used for penetration tests of the soil in measuring in situ soil.
Elasticity	The property of materials to return to their original shape and size after they have been loaded and deflected. Property is lost if material is loaded beyond its *Elastic Limit.* (A property opposite to that of *Plastic Deformation.)*
Elastic Moduli	One of the Elastic Constants, which also include Shear modulus, Bulk modulus, Poisson's ratio, Young's modulus. It is the ratio of stress (force per unit area) to strain (deformation per unit length).
Falling Weight Deflectometer (FWD)	Instrument to measure deflections of a pavement under load, using a falling weight.
Field Moisture Content (FMC)	See *Moisture Content.*
Grade	1. The longitudinal profile of a road. 2. To shape or smooth and earth, gravel or other surface by a grader or similar implement. 3. To arrange aggregate or other material according to particle sizes. 4. Designation given to size of sealing chips (1 to 6).
Grading	Particle size distribution (psd) of a material, e.g. aggregate.
Granular	material with psd >2mm
Gravel	psd = 200mm-2mm
Sand	psd = 2-0.06mm
Silt	psd = 0.06-0.002mm
Clay	psd = <0.002mm
Liquid Limit (LL)	See *Atterberg Limits Test.*
Modulus	See *Elasticity.*
Moisture Content (MC)	Quantity of water that can be removed from a subgrade soil by heating at 105 °C. Expressed as % of the dry weight.
Design (DMC)	MC used to design subgrade for a road.
Field (FMC)	MC of subgrade as it occurs in the field.
Optimum (OMC)	MC of soil at which compaction will produce highest *Dry Density.*
NAASRA	National Association of Australian State Road Authorities, now AUSTROADS.
Particle sizes (psd)	See *Grading.*
Pavement	The road structure that is constructed on the subgrade, and supports the traffic loading.

Plasticity Index (PI)	See *Atterberg Limits Test.*
Plastic Limit (PL)	See *Atterberg Limits Test.*
Resilient Modulus	A dynamic characteristic of a pavement material defined as the ratio of repeated stress to recoverable elastic strain. See *Modulus.*
Road	An area formed for vehicular traffic to travel over. Describes the area between kerbs or surface water channels, and includes median strips, shoulders, parking areas, cycle lanes.
Saturation (%)	Water has filled all voids in a soil.
Shoulder	Edges of a road. See also *Road.*
Shrinkage Limit	Water content of a soil below the *Plastic Limit* when no further shrinkage will take place.
Silt-size fraction	See *Grading.*
Soil	Any naturally occurring material, of mineral and organic origin, derived from, or forming part of, the weathering upper layers of the earth's crust. In this report, it constitutes the *Subgrade.*
Structural Number (SN)	A number used to describe the strength of a pavement, measured directly by CBR or Modulus, or indirectly by FWD or Benkelman Beam.
Sub-base	A lower structural layer of the pavement, consisting of *Aggregate*, rock or *Soil.*
Subgrade	The upper layer of the pavement foundation, i.e. top of a fill (imported and compacted material) or bottom of cut (in-place material, usually compacted).
Surface Course	The uppermost layer of a pavement.
UCS	Unconfined Compressive Strength test (NZS 3112:1986, Part 2).
USC	Universal Soil Classification (CL, ML, OL, CH, MH, OH - fine-grained soils: GW, GP, GM, GC, SW, SP, SM, SC - coarse-grained soils: abbreviations used in this classification).
Water Content	The mass of water which can be removed from a soil by heating to 105°C, expressed as % of dry mass (NZS 4407:1991, Part 3.1). See also *Moisture Content.*

Appendix 1 Summary Sheets from Testing Rounds

Test Pit Logs and In-Situ Test Results from First Round of Testing

Testing Round One

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Report N°: 613836
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Test Method Used:
NZS 4402:1986 Test 2.1 Determination of Water Content
NZS 4402:1986 Test 2.2 Determination of Liquid Limit
NZS 4402:1986 Test 2.2 Determination of Plastic Limit
NZS 4402:1986 Test 2.2 Determination of Plasticity Index
NZS 4402:1986 Test 5.1.4 Immersion in Water Method

TEST RESULTS SUMMARY

ROAD		Kohimarama Road, Kohimarama														
Test Pit No.		KO1								KO3						
Depth	(m)	0.2	0.3	0.6	0.7	0.9	1.2	1.35	1.5	0.3	0.6	0.9	1.2	1.5		
Water Content	(%)	28	37.3	39.9	53.4	50.3	54.5	53.8	39.1	24.4	33.1	31.7	27.5	30.7		
Bulk Density	(t/m³)		1.82							1.98						
Dry Density	(t/m³)		1.32							1.60						
Solid Density (assumed)	(t/m³)		2.67							2.67						
Air Voids	(%)		1.3							1						
Liquid Limit	(%)	59			92			115								
Plastic Limit	(%)	29			48			45								
Plasticity Index		30			44			70								
ROAD		Kohimarama Road, Kohimarama														
Test Pit No.		KO5								KO6						
Depth	(m)	0.3	0.6	0.9	1.2	1.5				0.3	0.6	0.9	1.2	1.5		
Water Content	(%)	35.8	44.8	47	47.3	52.6				33.2	45.8	46.3	47.3	51.5		
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															
Liquid Limit	(%)					118				49						
Plastic Limit	(%)					44				22						
Plasticity Index						74				27						
ROAD		Kohimarama Road, Kohimarama														
Test Pit No.		KO4								KO2						
Depth	(m)	0.3	0.6	0.9	1.2	1.5				0.3	0.6	0.9	1.2	1.5		
Water Content	(%)	28.1	33	32.4	29.6	25.5				27.6	43.7	51.2	47.8	40.9		
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids																

COMMENTS:

Entered by: IW Date: 21-01-01 Checked by: Date:

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Test Method Used:
NZS 4402:1986 Test 2.1 Determination of Water Content
NZS 4402:1986 Test 2.2 Determination of Liquid Limit
NZS 4402:1986 Test 2.2 Determination of Plastic Limit
NZS 4402:1986 Test 2.2 Determination of Plasticity Index
NZS 4402:1986 Test 5.1.4 Immersion in Water Method

TEST RESULTS SUMMARY

ROAD		Blockhouse Bay Road															
Test Pit No.		BB1								BB3							
Depth	(m)	0.3	0.6	0.9	1.2	1.5				0.3	0.6	0.8	0.9	1.2	1.5		
Water Content	(%)	33.4	33	31.2	32.6	34.1				47.1	60.5	45.5	44.8	44.9	42.6		
Bulk Density	(t/m³)																
Dry Density	(t/m³)																
Solid Density (assumed)	(t/m³)																
Air Voids	(%)																
Liquid Limit	(%)											73					
Plastic Limit	(%)											37					
Plasticity Index												36					
ROAD		Blockhouse Bay Road															
Test Pit No.		BB5								BB2							
Depth	(m)	0.3	0.6	0.9	1.2	1.5				0.1	0.3	0.6	0.9	1.2	1.5		
Water Content	(%)	34.4	46.4	63.5	49.3	45.5				29.1	50.6	32	38.4	32.1	30.9		
Bulk Density	(t/m³)	1.86									1.70						
Dry Density	(t/m³)	1.38									1.12						
Solid Density (assumed)	(t/m³)	2.65									2.65						
Air Voids	(%)	0.5									1.1						
Liquid Limit	(%)									49				68			
Plastic Limit	(%)									22				29			
Plasticity Index										27				39			
ROAD		Blockhouse Bay Road															
Test Pit No.		BB4								BB6							
Depth	(m)	0.3	0.6	0.9	1.2	1.5				0.3	0.6	0.9	1.2	1.5			
Water Content	(%)	58.9	52.3	53.9	49.9	52				60.1	51.1	56.4	53.6	55.1			
Bulk Density	(t/m³)																
Dry Density	(t/m³)																
Solid Density (assumed)	(t/m³)																
Air Voids																	

COMMENTS:

Entered by: ILD Date: 21-01-01 Checked by: Date:

GEOTECHNICS LTD.
23 MORGAN ST. NEWMARKET, AUCKLAND
TELEPHONE (09) 3556020 FAX (09) 3070265

Form No.:	
Form Date:	Jan 2001
File:\M:\iw\bartley\bartley	

Report N°. 613836
Page N°: 35 of 52

Test Method Used:
NZS 4402:1986 Test 2.1 Determination of Water Content
NZS 4402:1986 Test 2.2 Determination of Liquid Limit
NZS 4402:1986 Test 2.2 Determination of Plastic Limit
NZS 4402:1986 Test 2.2 Determination of Plasticity Index
NZS 4402:1986 Test 5.1.4 Immersion in Water Method

TEST RESULTS SUMMARY

ROAD		**Bristol Road, Whenuapai**														
Test Pit No.		BR1								BR3						
Depth	(m)	0.3	0.6	0.9	1.2	1.5				0.3	0.6	0.9	1.2	1.5		
Water Content	(%)	77.6	92.2	41.2	25.8	27.5				81.8	114	101	83.4	60.5		
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															
Liquid Limit	(%)											143				
Plastic Limit	(%)											80				
Plasticity Index												63				

ROAD		**Bristol Road, Whenuapai**														
Test Pit No.		BR5								BR6						
Depth	(m)	0.3	0.6	0.9	1.2	1.5				0.2	0.3	0.45	0.6	0.9	1.2	1.5
Water Content	(%)	94.8	108	62	46.4	40.5				73.6	98.1	79.7	83.8	30.6	31.2	30.1
Bulk Density	(t/m³)	1.44														
Dry Density	(t/m³)	0.74														
Solid Density (assumed)	(t/m³)	2.65														
Air Voids	(%)	1.9														
Liquid Limit	(%)									116		84				
Plastic Limit	(%)									81		52				
Plasticity Index										35		32				

ROAD		**Bristol Road, Whenuapai**														
Test Pit No.		BR4								BR2						
Depth	(m)	0.3	0.6	0.9	1.2	1.5				0.3	0.6	0.9	1.2	1.5		
Water Content	(%)	79	99.5	66	39.8	34.6				51.9	37	37.1	37	34.7		
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids																

COMMENTS:

Entered by: IWD Date: 21·01·01 Checked by: Date:

Testing Round Two

GEOTECHNICS LTD.
23 MORGAN ST. NEWMARKET, AUCKLAND
TELEPHONE (09) 3556020 FAX (09) 3070265

Form No.:	
Form Date:	Jan 2001
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Test Method Used: NZS 4402:1986 Test 2.1 Determination of Water Content

Our Ref: 613836/a
Client Ref: Sub-grade2
Date: 8 May 2001
Page 3 of 59

TEST RESULTS SUMMARY

ROAD		**Kohimarama Road, Kohimarama**														
Test Pit No.		KO1								KO3						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	27.8	39.6	40.4	48.5	54.3	55.3			27.5	25	33.9	29.9	31.4	33.3	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															
Liquid Limit	(%)															
Plastic Limit	(%)															
Plasticity Index																

ROAD		**Kohimarama Road, Kohimarama**														
Test Pit No.		KO5								KO6						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	20.5	33.4	43.1	46.3	50.1	50.4			24	29.6	45.1	46.1	46.9	49.1	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															
Liquid Limit	(%)															
Plastic Limit	(%)															
Plasticity Index																

ROAD		**Kohimarama Road, Kohimarama**														
Test Pit No.		KO4								KO2						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	22.4	27	31.2	33.7	34.8	28.3			21.9	29.5	41.4	49.2	28.9	21.6	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids																

COMMENTS:

Entered by: IW Date: 7.5.01 Checked by: RR Date: 7.5.01

Form No.:	
Form Date:	Jan 2001
File:\M:\iw\bartley\blockhouse	

Test Method Used: NZS 4402:1986 Test 2.1 Determination of Water Content

Our ref: 613836/a
Client Ref:Sub-grade
Date of Rep: 8 May 2001
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TEST RESULTS SUMMARY

ROAD		**Blockhouse Bay Road**														
Test Pit No.		BB1								BB3						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	34.6	35.4	34	31.3	32.4	33			50	53	54.5	47.8	46.8	40.8	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															
Liquid Limit	(%)															
Plastic Limit	(%)															
Plasticity Index																

ROAD		**Blockhouse Bay Road**														
Test Pit No.		BB5								BB2						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	35	57.3	54	44	49.6	51.6			29.5	33.9	32.6	32.1	30.8	32.1	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															
Liquid Limit	(%)															
Plastic Limit	(%)															
Plasticity Index																

ROAD		**Blockhouse Bay Road**														
Test Pit No.		BB4								BB6						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	25.8	49.5	49.1	60	50.9	45.1			28.5	55.2	45	51.2	48.3	49.6	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids																

COMMENTS:

Entered by: IW
Date: 7.5.01
Checked by: RR
Date: 7.5.01

GEOTECHNICS LTD.

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Form No.:	
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Test Method Used: NZS 4402:1986 Test 2.1 Determination of Water Content

OurRef:613836/a
Client Ref: Sub-grade2
Date:8 May 2001
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TEST RESULTS SUMMARY

ROAD		Bristol Road, Whenuapai														
Test Pit No.		BR1								BR3						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	84.9	81.7	79.4	31.8	30.4	31.6			53.5	90.1	116	103	38	34.4	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															
Liquid Limit	(%)															
Plastic Limit	(%)															
Plasticity Index																

ROAD		Bristol Road, Whenuapai														
Test Pit No.		BR5								BR6						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	43.7	55.8	36.8	37.7	34.3	36.9			51.3	58.1	39.8	38.1	35.2	31.6	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															
Liquid Limit	(%)															
Plastic Limit	(%)															
Plasticity Index																

ROAD		Bristol Road, Whenuapai														
Test Pit No.		BR4								BR2						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	40.7	54.9	109	75.6	47.6	29.8			81.9	97.1	105	31.9	28.5	31.5	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids																

COMMENTS:

Entered by: IW Date: 7.5.01 Checked by: RR Date: 7.5.01

Testing Round Three

GEOTECHNICS LTD.

23 MORGAN ST. NEWMARKET, AUCKLAND

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Form No.:	
Form Date:	Jan 2001
File:M:\iw\bartley\Kohi	

Test Method Used: NZS 4402:1986 Test 2.1 Determination of Water Content

Our Ref: 613836/b
Client Ref: Sub-grade3
Date: 4 Oct 2001
Page 3 of 56

TEST RESULTS SUMMARY

ROAD		**Kohimarama Road, Kohimarama**														
Test Pit No.		KO1								KO3						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	28.4	39.7	40.7	50.6	54.1	55.8			21.2	29.1	31.9	29.8	31	33.1	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															
Liquid Limit	(%)															
Plastic Limit	(%)															
Plasticity Index																

ROAD		**Kohimarama Road, Kohimarama**														
Test Pit No.		KO5								KO6						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	18.1	40.3	45.8	46.4	48.8	51.7			26.7	27	42	47.2	47.5	48.5	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															
Liquid Limit	(%)															
Plastic Limit	(%)															
Plasticity Index																

ROAD		**Kohimarama Road, Kohimarama**														
Test Pit No.		KO4								KO2						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	23.9	28.7	34.4	31.2	35.7	29.5			27.2	30.3	34.5	51.4	43.7	36.4	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids																

COMMENTS:

Entered by: IWS Date: 4/10/01 Checked by: RR Date: 19.10.01

GEOTECHNICS LTD.
23 MORGAN ST. NEWMARKET, AUCKLAND
TELEPHONE (09) 3556020 FAX (09) 3070265

Form No.:	
Form Date:	Jan 2001
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Test Method Used: NZS 4402:1986 Test 2.1 Determination of Water Content

Our ref: 613836/b
Client Ref:Sub-grade
Date tested: 8 Oct 2001
Page 21 of 56

TEST RESULTS SUMMARY

ROAD		Blockhouse Bay Road														
Test Pit No.		BB1								BB3						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	36.8	33.8	32.6	30.9	32.1	34.2			48	49.6	50.9	45.3	45.5	48.4	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															
Liquid Limit	(%)															
Plastic Limit	(%)															
Plasticity Index																
ROAD		Blockhouse Bay Road														
Test Pit No.		BB5								BB2						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	36.8	57	56.8	53.5	51.2	53.3			34.2	35.6	36.5	35.8	31.5	29.7	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															
Liquid Limit	(%)															
Plastic Limit	(%)															
Plasticity Index																
ROAD		Blockhouse Bay Road														
Test Pit No.		BB4								BB6						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	30.8	29.2	47.1	63.3	52.2	47.7			21.9	53.3	47.2	48.5	46.5	51.2	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															

COMMENTS:

Entered by: Iws Date: 8.10.01 Checked by: RR Date: 19.10.01

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Form No.:	
Form Date:	Jan 2001
File:\M:\iw\bartley\visit 3	

Test Method Used: NZS 4402:1986 Test 2.1 Determination of Water Content

OurRef: 613836/b
Client Ref: Sub-grade3
Date:25 Sep 2001
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TEST RESULTS SUMMARY

ROAD		**Bristol Road, Whenuapai**														
Test Pit No.		BR1								BR3						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	46.3	71	87.5	40.7	29.8	31.7			49.9	68.7	112	94.9	52.6	36.9	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															
Liquid Limit	(%)															
Plastic Limit	(%)															
Plasticity Index																
ROAD		**Bristol Road, Whenuapai**														
Test Pit No.		BR5								BR6						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	26.8	51.8	51.7	35.1	38.6	38.6			49.3	65.3	41.9	35.9	37	31	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															
Liquid Limit	(%)															
Plastic Limit	(%)															
Plasticity Index																
ROAD		**Bristol Road, Whenuapai**														
Test Pit No.		BR4								BR2						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	85.4	76.5	109	85.7	31.1	37.9			64.2	82.3	93.5	31.2	33.5	28.6	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids																

COMMENTS:

Entered by: IW Date: 25.9.01 Checked by: RR Date: 19-10.01

Testing Round Four

GEOTECHNICS LTD.
23 MORGAN ST. NEWMARKET, AUCKLAND
TELEPHONE (09) 3556020 FAX (09) 3070265

Form No.:	
Form Date:	Jan 2001
File:\M:\iw\bartley\Kohi	

Test Method Used: NZS 4402:1986 Test 2.1 Determination of Water Content

Our Ref: 613836/c
Client Ref: Sub-grade4
Date: 12 Feb 2002
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TEST RESULTS SUMMARY

ROAD		Kohimarama Road, Kohimarama														
Test Pit No.		KO1								KO3						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	26.3	40.2	39.7	39.3	39.4	44.3			17.4	19.4	21.9	29	30.7	31.5	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															
Liquid Limit	(%)															
Plastic Limit	(%)															
Plasticity Index																
ROAD		Kohimarama Road, Kohimarama														
Test Pit No.		KO5								KO6						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	16.7	23.1	34.6	45.3	45.8	37			24.3	21.2	29.9	38.3	40.4	41.4	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															
Liquid Limit	(%)															
Plastic Limit	(%)															
Plasticity Index																
ROAD		Kohimarama Road, Kohimarama														
Test Pit No.		KO4								KO2						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	25.4	28.4	31.1	35.9	35.4	30.3			23.7	24.7	26.6	31.6	38.6	49.6	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids																

COMMENTS:

Entered by: IW Date: 12/2/02 Checked by: AB Date: 28/2/02.

GEOTECHNICS LTD.

23 MORGAN ST. NEWMARKET, AUCKLAND

TELEPHONE (09) 3556020 FAX (09) 3070265

Form No.:	
Form Date:	Jan 2001
File:\M:\iw\bartley\blockhouse	

Test Method Used: NZS 4402:1986 Test 2.1 Determination of Water Content

Our ref: 613836/c
Client Ref:Sub-grade4
Date tested: 21/2/02
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TEST RESULTS SUMMARY

ROAD		**Blockhouse Bay Road**														
Test Pit No.		BB1								BB3						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	37.7	35.3	34.3	32	31.2	30.7			47.7	55.1	57.2	52.8	50.6	46.6	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															
Liquid Limit	(%)															
Plastic Limit	(%)															
Plasticity Index																

ROAD		**Blockhouse Bay Road**														
Test Pit No.		BB5								BB2						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	32.8	53.7	53.2	51.8	43.8	48.2			36.4	33.4	34.2	30.8	32.4	33.6	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids	(%)															
Liquid Limit	(%)															
Plastic Limit	(%)															
Plasticity Index																

ROAD		**Blockhouse Bay Road**														
Test Pit No.		BB4								BB6						
Depth	(m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5	
Water Content	(%)	28.3	30.6	32.3	29.5	33.7	39.8			20.5	43.7	46.6	46.8	51.2	55.4	
Bulk Density	(t/m³)															
Dry Density	(t/m³)															
Solid Density (assumed)	(t/m³)															
Air Voids																

COMMENTS:

Entered by: IW Date: 24/2/02 Checked by: AB Date: 28/2/02

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Test Method Used: NZS 4402:1986 Test 2.1 Determination of Water Content

OurRef: 613836/c
Client Ref: Sub-grade4
Date:12 Feb 2002
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TEST RESULTS SUMMARY

ROAD	**Bristol Road, Whenuapai**															
Test Pit No.	BR1								BR3							
Depth (m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5		
Water Content (%)	71.9	81	90.4	45.4	30.9	31.9			88.1	89.8	110	113	110	105		
Bulk Density (t/m³)																
Dry Density (t/m³)																
Solid Density (assumed) (t/m³)																
Air Voids (%)																
Liquid Limit (%)																
Plastic Limit (%)																
Plasticity Index																
ROAD	**Bristol Road, Whenuapai**															
Test Pit No.	BR5								BR6							
Depth (m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5		
Water Content (%)	47.8	61.3	57.5	40.2	34	31.7			45.6	55.4	51.6	43	36.9	33		
Bulk Density (t/m³)																
Dry Density (t/m³)																
Solid Density (assumed) (t/m³)																
Air Voids (%)																
Liquid Limit (%)																
Plastic Limit (%)																
Plasticity Index																
ROAD	**Bristol Road, Whenuapai**															
Test Pit No.	BR4								BR2							
Depth (m)	CBR	0.3	0.6	0.9	1.2	1.5			CBR	0.3	0.6	0.9	1.2	1.5		
Water Content (%)	69.3	65.4	98.5	100	72.5	64.5			75.1	84.4	94.7	68.6	39.6	27.9		
Bulk Density (t/m³)																
Dry Density (t/m³)																
Solid Density (assumed) (t/m³)																
Air Voids																

COMMENTS:

Entered by: Date: 12/2/02 Checked by: Date: 28/2/02

Test Pit Logs from First Round of Testing

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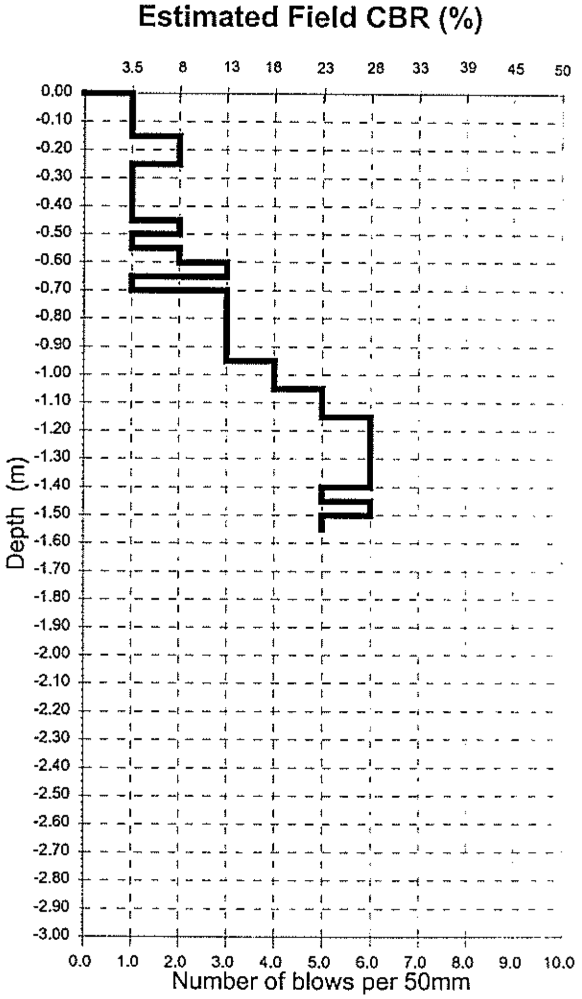
Job Name:	**CBR Investigations**	Job No.:	**613836**	Client Ref.:	**Bartley RTU**
Client:	**Bartley Consultants**	Contractor:	**Geotechnics**		
Test Method Used:	NZS 4402 : 1988 Test 6.5.2	Dynamic Cone Penetrometer			

PAVEMENT INVESTIGATION LOG TEST REPORT

Project:	**CBR Investigations**	Sampled By:	**IW**
Location:	**Kohimarama Road**	Date Sampled:	**30/11/2000**
Lane:	**Left hand wheel-track**	Sampling Method:	**Test pit excavation**
Pit Location.:	**Opposite house No154**	Sample Condition:	**Disturbed**
Pavement Pit No.:	KO1	Date Received:	**30/11/2000**

Depth (mm)	Pavement Description
0 - 100	**Asphalt, hotmix, several different layers, surface in good condition**
100 - 200	**Silty GRAVEL, fine to medium, GAP40, dense, slightly moist**
200 - 400	**Silty GRAVEL, fine to medium, GAP65, dense, slightly moist, crushed scoria matrix**
400	**Top of sub-grade level**
0 - 200	**Silty CLAY, stiff to very stiff, medium to high plasticity, slightly moist, dark greenish grey**
200 - 800	**Silty CLAY, very stiff, slightly moist, medium to high plasticity, light grey with orange mottles**
800 - 1500	**CLAY, very stiff, high plasticity, slightly moist, light grey**
1500	**End of auger**



Basecourse sample recovered at:	N/A	(mm)
Sub-base sample recovered at:	N/A	(mm)
Subgrade sample recovered at:	5 depths	(mm)
Depth from ground surface to: commencement of penetration:	400	(mm)

Density By Nuclear Densometer

	Basecourse	Subgrade
Wet Density (t/m3):	N/A	N/A
Dry Density (t/m3):	N/A	N/A
Water Content (%):	N/A	N/A

COMMENTS:

The estimated CBR values are based on Figure 5.2 Correlation of Dynamic Cone Penetration and CBR, AUSTROADS (1992) "Pavement Design - A guide to the Structural Design of Road Pavements"

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Tested By: IW Date Tested 30/11/00 Checked By: AB Date: 22/01/01

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Form No.:	S15b
Form Date:	Oct 1998
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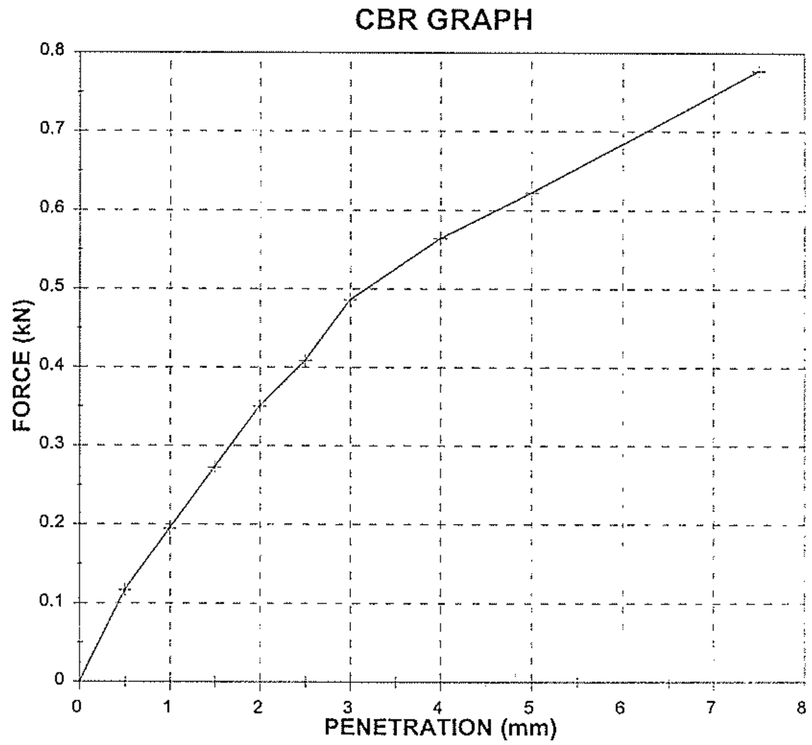
Road.: Kohimarama Road
Page 5 of 52
Site: Test pit KO1
Job Name: BartleyRTU
Job No.: 613836
Location: Opposite No 154
Lane.: Left hand wheel-track
Depth: -400 (mm)
Test Method Used: NZS 4402 1986 Test 6.1.3 California Bearing Ratio - In-situ method
NZS 4402 1986 Test 2.1 Determination of the Water Content

CALIFORNIA BEARING RATIO TEST- IN-SITU METHOD

Proving Ring No. : RO300
Proving Ring constant : 0.0778 (kN/div)
Water content: 28.0 (%)
Dial gauge No.: RO253

PENETRATION (mm)	FORCE (div)	FORCE (kN)
0.00	0.00	0.00
0.50	1.50	0.12
1.00	2.50	0.19
1.50	3.50	0.27
2.00	4.50	0.35
2.50	5.25	0.41
3.00	6.25	0.49
4.00	7.25	0.56
5.00	8.00	0.62
7.50	10.00	0.78



CBR RESULTS:

2.5 mm		
CORRECTED FORCE	(div)	5
	F (kN)	0.41
CBR (%)	(= F*100/13.2)	3.1
5.0 mm		
CORRECTED FORCE	(div)	8
	F (kN)	0.62
CBR (%)	(= F*100/20)	3.1
FINAL CBR VALUE:		3

Linear Regression is needed (Y/N) ? N
Initial Peneration Reading (mm): 0.00
Surcharge (Kg): 6
Base weight diameter (mm): 150
Rate of penetration by plunger (mm/min): 1/1

COMMENT:
Test performed at 400mm below top of pavement layer

MATERIAL DESCRIPTION:
As per pit log

Tested by: IW Date: 30/11/00 Checked by: AR Date: 22/01/01

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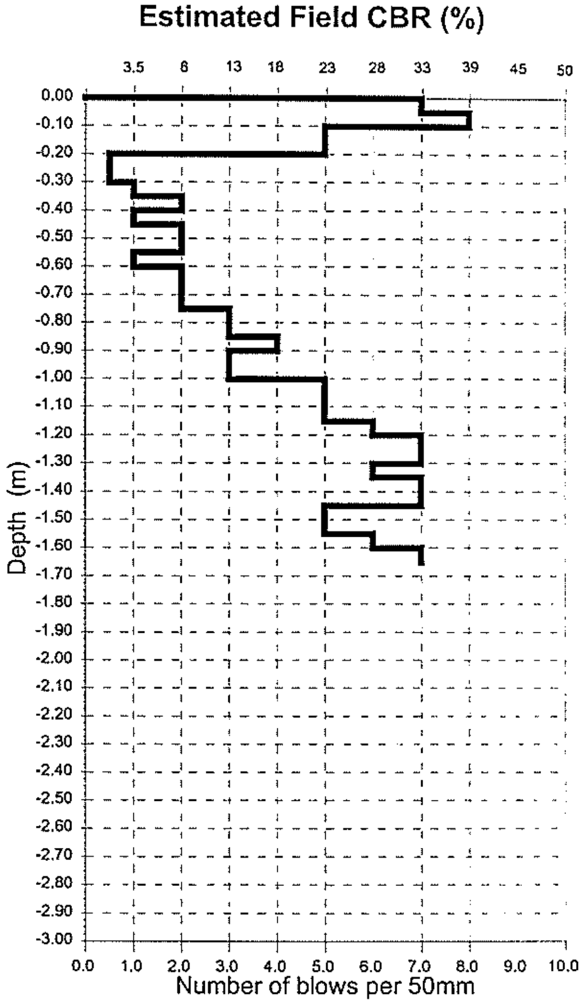
Job Name: **CBR Investigations** Job No.: **613836** Client Ref.: **Bartley RTU**
Client: **Bartley Consultants** Contractor: **Geotechnics**
Test Method Used: NZS 4402 : 1988 Test 6.5.2 Dynamic Cone Penetrometer

PAVEMENT INVESTIGATION LOG TEST REPORT

Project: **CBR Investigations**
Location: **Kohimarama Road**
Lane: **Left hand wheel-track**
Pit Location.: **Opposite house No148**
Pavement Pit No.: KO3

Sampled By: **IW**
Date Sampled: **30/11/2000**
Sampling Method: **Test pit excavation**
Sample Condition: **Disturbed**
Date Received: **30/11/2000**

Depth (mm)	Pavement Description
0 - 100	**Asphalt, hotmix, several different layers, surface in good condition**
100 - 180	**Silty GRAVEL, fine to medium, GAP40, crushed scoria, dense, slightly moist**
180 - 470	**Silty GRAVEL, fine to medium, GAP65, dense to very dense, slightly moist**
470	**Top of sub-grade level**
0 - 200	**Silty sandy CLAY, very stiff, medium to high plasticity, slightly moist, dark brown and grey**
200 - 350	**Silty CLAY, very stiff, slightly moist, medium to high plasticity, grey with light brown mottles**
350 - 1500	**Slightly silty CLAY, very stiff, medium plasticity, slightly moist, light grey**
1500	**End of auger**



Basecourse sample recovered at:	N/A	(mm)
Sub-base sample recovered at:	N/A	(mm)
Subgrade sample recovered at:	5 depths	(mm)
Depth from ground surface to: commencement of penetration:	500	(mm)

Density By Nuclear Densometer

	Basecourse	Subgrade
Wet Density (t/m3):	N/A	N/A
Dry Density (t/m3):	N/A	N/A
Water Content (%):	N/A	N/A

COMMENTS:
The estimated CBR values are based on Figure 5.2 Correlation of Dynamic Cone Penetration and CBR, AUSTROADS (1992) "Pavement Design - A guide to the Structural Design of Road Pavements"

IANZ Accreditation does not apply

Tested By: IW Date Tested 30/11/00 Checked By: AB Date: 22/01/01

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Form No.:	S15b
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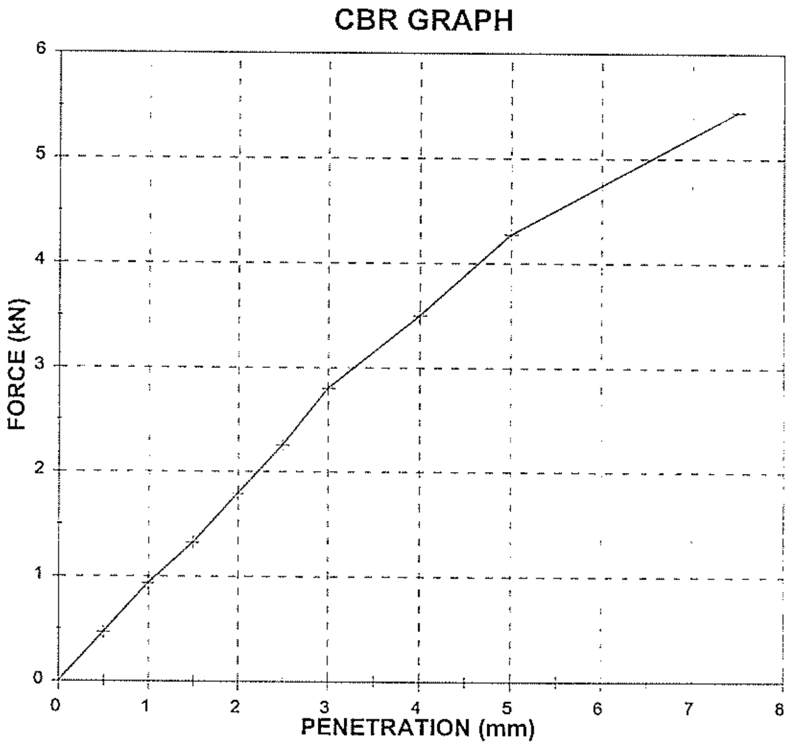
Road.: Kohimarama Road
Site: Test pit KO3
Job Name: BartleyRTU
Job No.: 613836
Location: Opposite No 148
Lane.: Left hand wheel-track
Depth: -470 (mm)
Test Method Used: NZS 4402 1986 Test 6.1.3 California Bearing Ratio - In-situ method
NZS 4402 1986 Test 2.1 Determination of the Water Content

CALIFORNIA BEARING RATIO TEST- IN-SITU METHOD

Proving Ring No. : RO300
Proving Ring constant : 0.0778 (kN/div)
Water content: 24.4 (%)
Dial gauge No.: RO253

PENETRATION	FORCE	
(mm)	(div)	(kN)
0.00	0.00	0.00
0.50	6.00	0.47
1.00	12.00	0.93
1.50	17.00	1.32
2.00	23.00	1.79
2.50	29.00	2.26
3.00	36.00	2.80
4.00	45.00	3.50
5.00	55.00	4.28
7.50	70.00	5.45



CBR RESULTS:

2.5 mm		
CORRECTED	(div)	29
FORCE	F (kN)	2.26
CBR (%)	(= F*100/13.2)	17.1
5.0 mm		
CORRECTED	(div)	55
FORCE	F (kN)	4.28
CBR (%)	(= F*100/20)	21.4
FINAL CBR VALUE:		20

Linear Regression is needed (Y/N) ? N
Initial Peneration Reading (mm): 0.00
Surcharge (Kg): 6
Base weight diameter (mm): 150
Rate of penetration by plunger (mm/min): 1/1

COMMENT:
Test performed at 470mm below top of pavement layer

MATERIAL DESCRIPTION:
As per pit log

Tested by: IW
Date: 30/11/00
Checked by: AB
Date: 22/01/01

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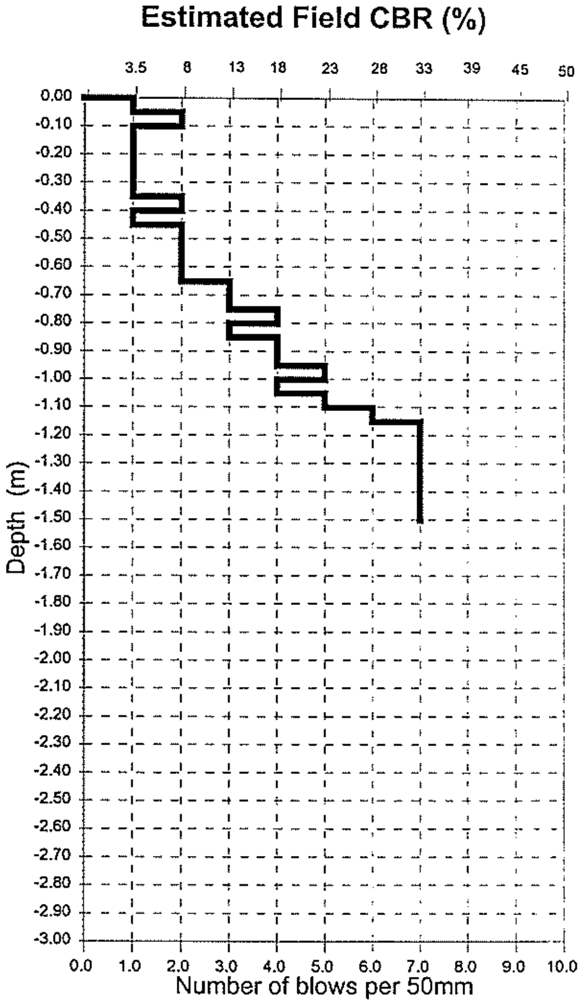
Job Name:	**CBR Investigations**	Job No.:	**613836**	Client Ref.:	**Bartley RTU**
Client:	**Bartley Consultants**	Contractor:	**Geotechnics**		
Test Method Used:	NZS 4402 : 1988 Test 6.5.2	Dynamic Cone Penetrometer			

PAVEMENT INVESTIGATION LOG TEST REPORT

Project:	**CBR Investigations**	Sampled By:	**IW**
Location:	**Kohimarama Road**	Date Sampled:	**19/12/2000**
Lane:	**Left hand wheel-track**	Sampling Method:	**Test pit excavation**
Pit Location.:	**Opposite house No142**	Sample Condition:	**Disturbed**
Pavement Pit No.:	KO5	Date Received:	**19/12/2000**

Depth (mm)	Pavement Description
0 - 40	**Asphalt, hotmix, surface in good condition**
40 - 100	**Silty GRAVEL, GAP40. dense. bitumen impregnated**
100 - 160	**Silty GRAVEL, GAP20, crushed scoria, slightly moist, light brown**
160 - 300	**Silty GRAVEL, fine to medium, GAP65, dense, slightly moist**
300	**Top of sub-grade level**
0 - 900	**Silty CLAY, stiff, slightly moist, medium to high plasticity, grey with light brown mottles**
900 - 1500	**Slightly silty CLAY, stiff to very stiff, medium plasticity, slightly moist, grey mottled orange and brown**
1500	**End of auger**



Basecourse sample recovered at:	N/A	(mm)
Sub-base sample recovered at:	N/A	(mm)
Subgrade sample recovered at:	5 depths	(mm)
Depth from ground surface to:	300	(mm)
commencement of penetration:		

Density By Nuclear Densometer

	Basecourse	Subgrade
Wet Density (t/m3):	N/A	N/A
Dry Density (t/m3):	N/A	N/A
Water Content (%):	N/A	N/A

COMMENTS:

The estimated CBR values are based on Figure 5.2 Correlation of Dynamic Cone Penetration and CBR, AUSTROADS (1992) "Pavement Design - A guide to the Structural Design of Road Pavements"

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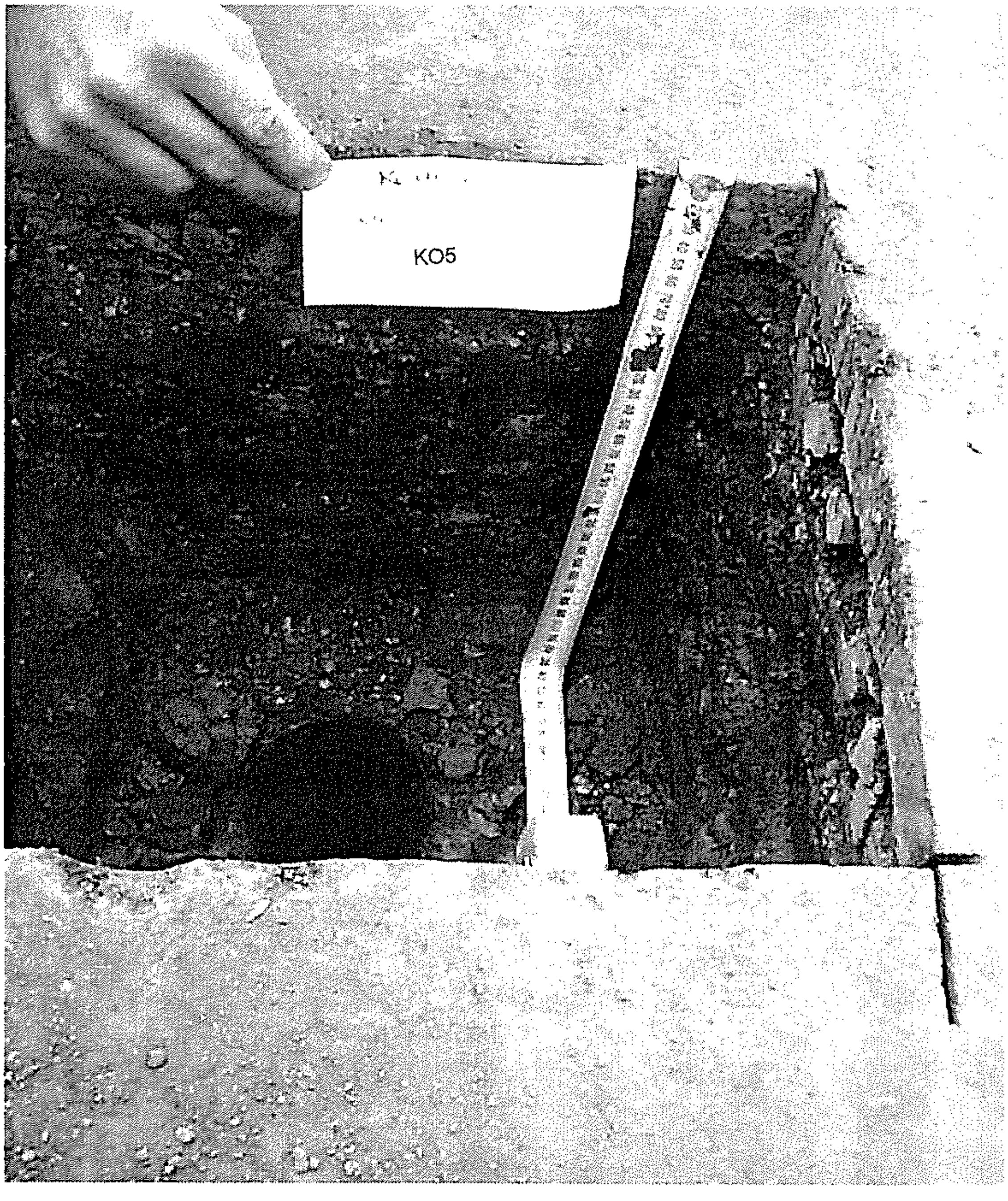
Tested By:	IW	Date Tested	19/12/00	Checked By:	AB	Date:	22/01/01

Kohimarama Road



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Road.: Kohimarama Road

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Site: Test pit KO5 Job Name: BartleyRTU Job No.: 613836

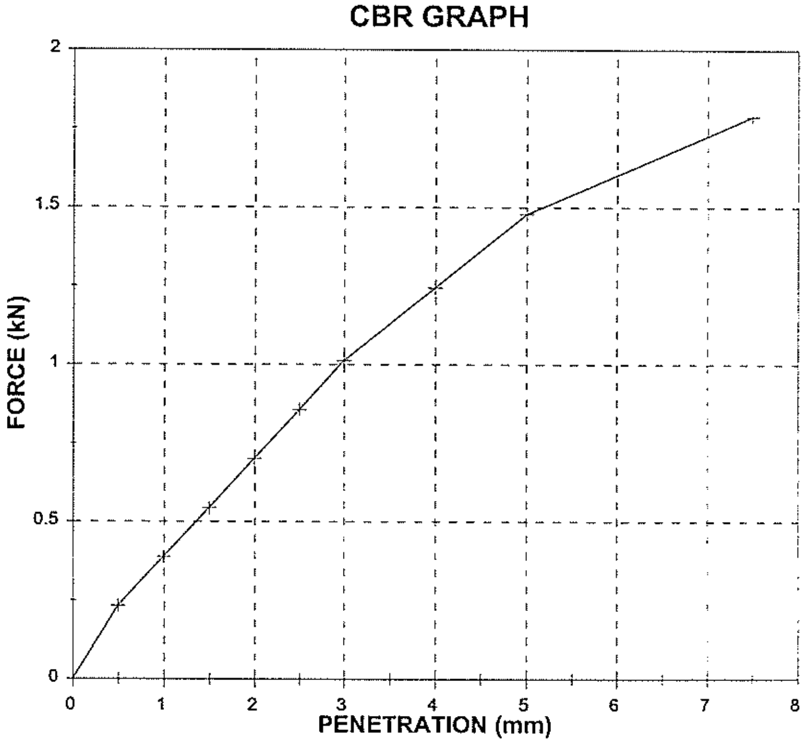
Location: Opposite No 142 Lane.: Left hand wheel-track Depth: -300 (mm)

Test Method Used: NZS 4402 1986 Test 6.1.3 California Bearing Ratio - In-situ method
NZS 4402 1986 Test 2.1 Determination of the Water Content

CALIFORNIA BEARING RATIO TEST- IN-SITU METHOD

Proving Ring No. :	RO300		Water content:	19.8	(%)
Proving Ring constant :	0.0778	(kN/div)	Dial gauge No.:	RO253	

PENETRATION (mm)	FORCE (div)	FORCE (kN)
0.00	0.00	0.00
0.50	3.00	0.23
1.00	5.00	0.39
1.50	7.00	0.54
2.00	9.00	0.70
2.50	11.00	0.86
3.00	13.00	1.01
4.00	16.00	1.24
5.00	19.00	1.48
7.50	23.00	1.79



CBR RESULTS:

2.5 mm		
CORRECTED FORCE	(div)	11
	F (kN)	0.86
CBR (%)	(= F*100/13.2)	6.5
5.0 mm		
CORRECTED FORCE	(div)	19
	F (kN)	1.48
CBR (%)	(= F*100/20)	7.4
FINAL CBR VALUE:		7

Linear Regression is needed (Y/N) ?	N
Initial Peneration Reading (mm):	0.00
Surcharge (Kg):	6
Base weight diameter (mm):	150
Rate of penetration by plunger (mm/min):	1/1

COMMENT:
Test performed at 300mm below top of pavement layer

MATERIAL DESCRIPTION:
As per pit log

Tested by: IW Date: 8/12/00 Checked by: AB Date: 22/01/01

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Form Date:	Nov 1998
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Job Name: **CBR Investigations** Job No.: **613836** Client Ref.: **Bartley RTU**
Client: **Bartley Consultants** Contractor: **Geotechnics**
Test Method Used: NZS 4402 : 1988 Test 6.5.2 Dynamic Cone Penetrometer

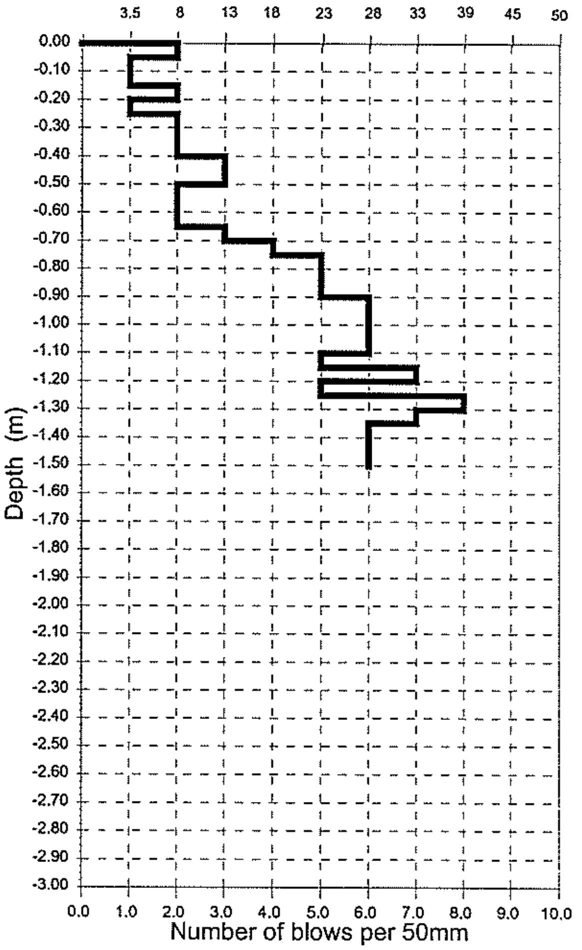
PAVEMENT INVESTIGATION LOG TEST REPORT

Project: **CBR Investigations**
Location: **Kohimarama Road**
Lane: **Centre- line of the road**
Pit Location.: **Adjacent to test pit No 3**
Pavement Pit No.: KO6

Sampled By: **IW**
Date Sampled: **01/12/2000**
Sampling Method: **Test pit excavation**
Sample Condition: **Disturbed**
Date Received: **01/12/2000**

Depth (mm)	Pavement Description
0 - 110	**Asphalt, hotmix, several layers, surface in good condition**
110 - 160	**Silty GRAVEL, fine to medium, GAP40, dense, slightly moist**
160 - 200	**Silty sandy GRAVEL, sands to fine, GAP20, dense, slightly moist, brown**
200 - 400	**Silty GRAVEL, fine to medium, GAP65, dense, slightly moist**
400	**Top of sub-grade level**
0 - 150	**Sandy silty CLAY, stiff, low plasticity, slightly moist, dark grey and brown**
150 - 350	**Silty CLAY, medium to high plasticity, stiff, slightly moist, light grey and brown**
350 - 1500	**Slightly silty CLAY, stiff to very stiff, medium plasticity, slightly moist, grey mottled orange and brown**
1500	**End of auger**

Estimated Field CBR (%)



Basecourse sample recovered at:	N/A	(mm)
Sub-base sample recovered at:	N/A	(mm)
Subgrade sample recovered at:	5 depths	(mm)
Depth from ground surface to: commencement of penetration:	400	(mm)

Density By Nuclear Densometer

	Basecourse	Subgrade
Wet Density (t/m3):	N/A	N/A
Dry Density (t/m3):	N/A	N/A
Water Content (%):	N/A	N/A

COMMENTS:

The estimated CBR values are based on Figure 5.2 Correlation of Dynamic Cone Penetration and CBR, AUSTROADS (1992) "Pavement Design - A guide to the Structural Design of Road Pavements"

IANZ Accreditation does not apply

Tested By: IW Date Tested 01/12/00 Checked By: AB Date: 22/01/01

Kohimarama Road, Kohimarama

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Form No.:	S15b
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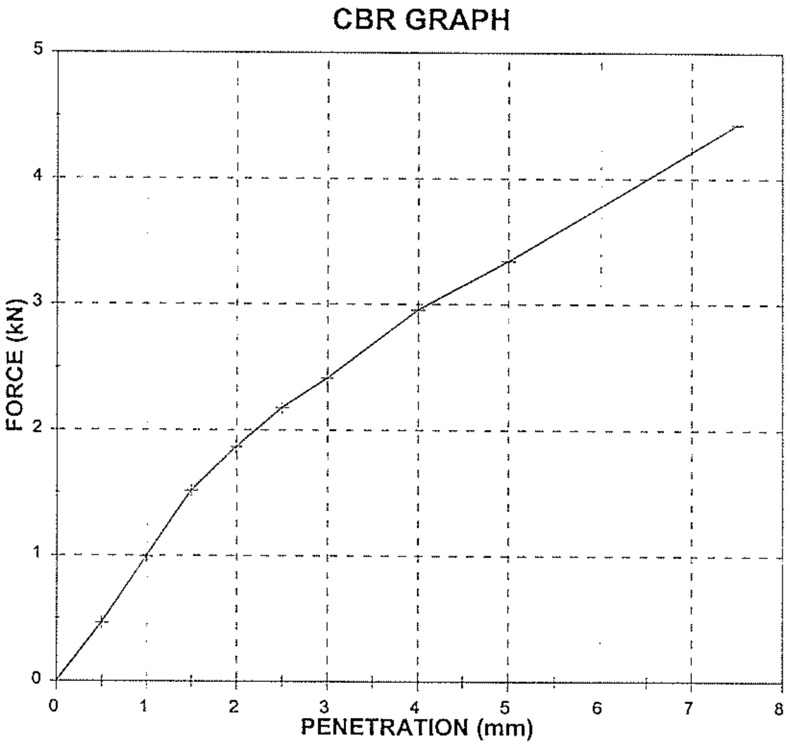
Road.: Kohimarama Road
Site: Test pit KO6
Job Name: BartleyRTU
Job No.: 613836
Location: Opposite No 142
Lane.: Centre of road
Depth: -400 (mm)
Test Method Used: NZS 4402 1986 Test 6.1.3 California Bearing Ratio - In-situ method
NZS 4402 1986 Test 2.1 Determination of the Water Content

CALIFORNIA BEARING RATIO TEST- IN-SITU METHOD

Proving Ring No. : RO300
Proving Ring constant : 0.0778 (kN/div)
Water content: 26.4 (%)
Dial gauge No.: RO253

PENETRATION (mm)	FORCE (div)	FORCE (kN)
0.00	0.00	0.00
0.50	6.00	0.47
1.00	12.75	0.99
1.50	19.50	1.52
2.00	24.00	1.87
2.50	28.00	2.18
3.00	31.00	2.41
4.00	38.00	2.96
5.00	43.00	3.35
7.50	57.00	4.43



CBR RESULTS:

2.5 mm		
CORRECTED FORCE	(div)	28
	F (kN)	2.18
CBR (%)	(= F*100/13.2)	16.5
5.0 mm		
CORRECTED FORCE	(div)	43
	F (kN)	3.35
CBR (%)	(= F*100/20)	16.7
FINAL CBR VALUE:		17

Linear Regression is needed (Y/N) ?	N
Initial Peneration Reading (mm):	0.00
Surcharge (Kg):	6
Base weight diameter (mm):	150
Rate of penetration by plunger (mm/min):	1/1

COMMENT:
Test performed at 400mm below top of pavement layer

MATERIAL DESCRIPTION:
As per pit log

Tested by: IW
Date: 01/12/00
Checked by: AR
Date: 22/01/01

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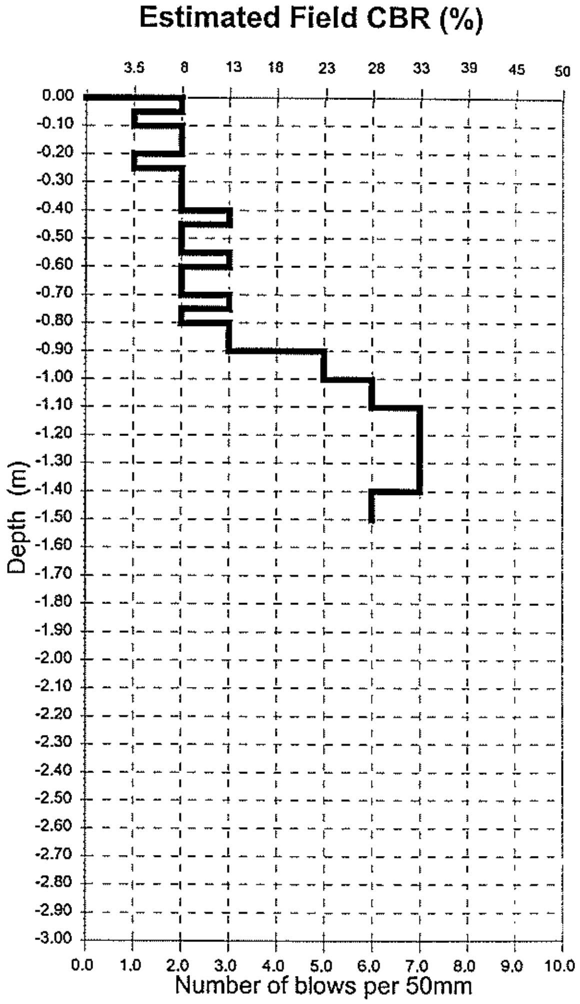
Job Name:	**CBR Investigations**	Job No.:	**613836**	Client Ref.:	**Bartley RTU**
Client:	**Bartley Consultants**	Contractor:	**Geotechnics**		
Test Method Used:	NZS 4402 : 1988 Test 6.5.2	Dynamic Cone Penetrometer			

PAVEMENT INVESTIGATION LOG TEST REPORT

Project:	**CBR Investigations**	Sampled By:	**IW**
Location:	**Kohimarama Road**	Date Sampled:	**01/12/2000**
Lane:	**Centre- line of the road**	Sampling Method:	**Test pit excavation**
Pit Location.:	**Adjacent to test pit No 2**	Sample Condition:	**Disturbed**
Pavement Pit No.:	KO4	Date Received:	**01/12/2000**

Depth (mm)	Pavement Description
0 - 110	**Asphalt, hotmix, several layers, surface in good condition**
110 - 250	**Silty GRAVEL, fine to medium, GAP40, dense, slightly moist, crushed scoria, reddish brown**
250 - 500	**Silty GRAVEL, fine to medium, GAP65, dense, slightly moist**
500	**Top of sub-grade level**
0 - 250	**Sandy silty CLAY, stiff, low plasticity, slightly moist, dark grey and brown**
250 - 450	**Silty CLAY, medium to high plasticity, stiff, slightly moist, light grey and brown**
450 - 1500	**Slightly silty CLAY, stiff to very stiff, medium plasticity, slightly moist, grey mottled orange and brown**
1500	**End of auger**



Basecourse sample recovered at:	N/A	(mm)
Sub-base sample recovered at:	N/A	(mm)
Subgrade sample recovered at:	5 depths	(mm)
Depth from ground surface to:	500	(mm)
commencement of penetration:		

Density By Nuclear Densometer

	Basecourse	Subgrade
Wet Density (t/m3):	N/A	N/A
Dry Density (t/m3):	N/A	N/A
Water Content (%):	N/A	N/A

COMMENTS:

The estimated CBR values are based on Figure 5.2 Correlation of Dynamic Cone Penetration and CBR, AUSTROADS (1992) "Pavement Design - A guide to the Structural Design of Road Pavements"

IANZ Accreditation does not apply

Tested By:	IW	Date Tested	01/12/00	Checked By:	AB	Date:	22/01/01

Kohimarama Road, Kohimarama

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Form No.:	S15b
Form Date:	Oct 1998
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Road.: Kohimarama Road

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Site: Test pit KO4 Job Name: BartleyRTU Job No.: 613836

Location: Opposite No 148 Lane.: Centre of road Depth: -500 (mm)

Test Method Used: NZS 4402 1986 Test 6.1.3 California Bearing Ratio - In-situ method
NZS 4402 1986 Test 2.1 Determination of the Water Content

CALIFORNIA BEARING RATIO TEST- IN-SITU METHOD

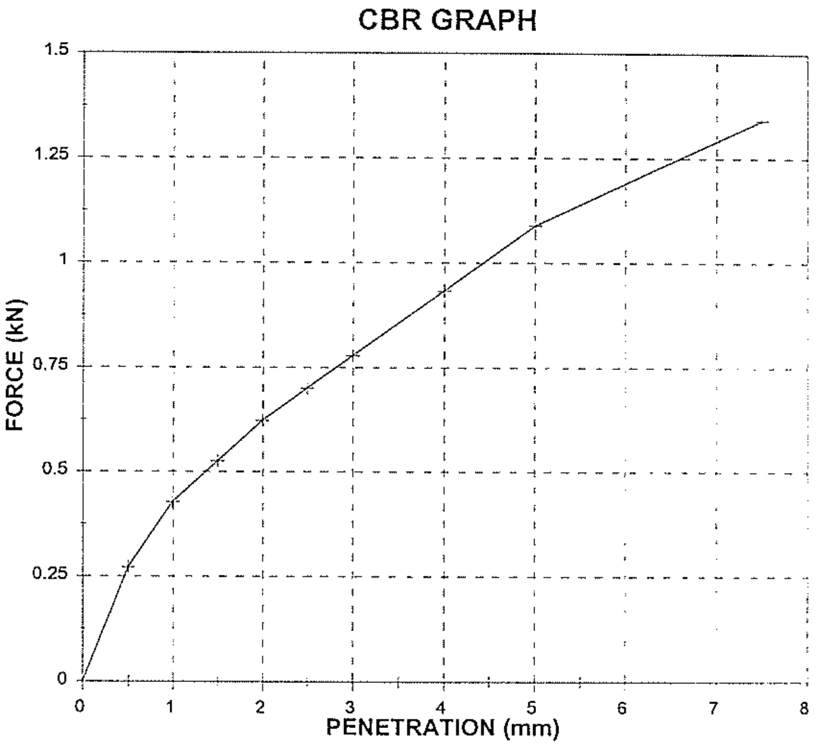
Proving Ring No. : RO300

Proving Ring constant : 0.0778 (kN/div)

Water content: 22.8 (%)

Dial gauge No.: RO253

PENETRATION (mm)	FORCE (div)	FORCE (kN)
0.00	0.00	0.00
0.50	3.50	0.27
1.00	5.50	0.43
1.50	6.75	0.53
2.00	8.00	0.62
2.50	9.00	0.70
3.00	10.00	0.78
4.00	12.00	0.93
5.00	14.00	1.09
7.50	17.25	1.34



CBR RESULTS:

2.5 mm		
CORRECTED FORCE	(div)	9
	F (kN)	0.70
CBR (%)	(= F*100/13.2)	5.3
5.0 mm		
CORRECTED FORCE	(div)	14
	F (kN)	1.09
CBR (%)	(= F*100/20)	5.4
FINAL CBR VALUE:		5

Linear Regression is needed (Y/N) ? N

Initial Peneration Reading (mm): 0.00

Surcharge (Kg): 6

Base weight diameter (mm): 150

Rate of penetration by plunger (mm/min): 1/1

COMMENT:
Test performed at 500mm below top of pavement layer

MATERIAL DESCRIPTION:
As per pit log

Tested by: IW Date: 01/12/00 Checked by: AB Date: 22/01/01

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Form No.:	
Form Date:	Nov 1998
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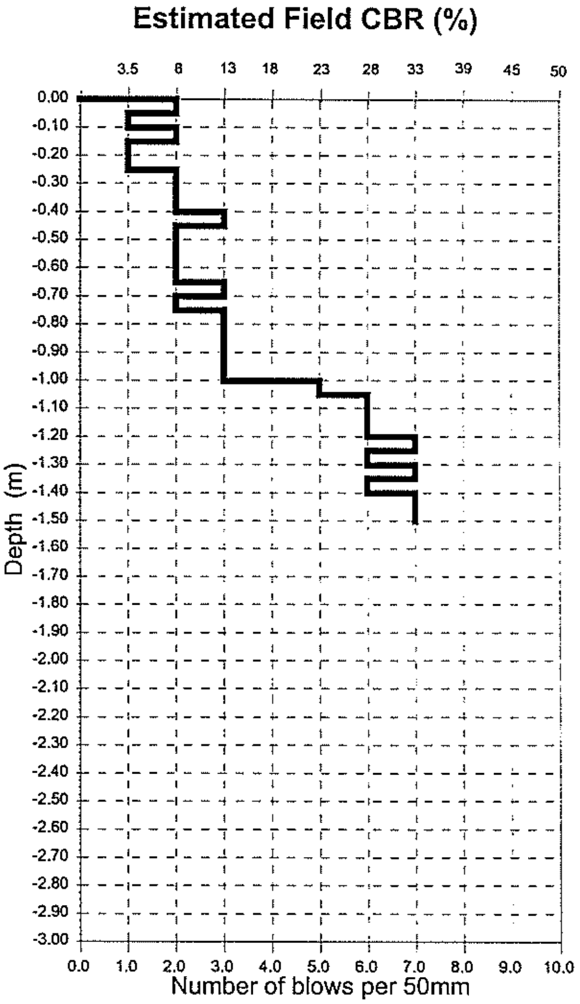
Job Name:	**CBR Investigations**	Job No.:	**613836**	Client Ref.:	**Bartley RTU**
Client:	**Bartley Consultants**	Contractor:	**Geotechnics**		

Test Method Used: NZS 4402 : 1988 Test 6.5.2 Dynamic Cone Penetrometer

PAVEMENT INVESTIGATION LOG TEST REPORT

Project:	**CBR Investigations**	Sampled By:	**IW**
Location:	**Kohimarama Road**	Date Sampled:	**01/12/2000**
Lane:	**Centre- line of the road**	Sampling Method:	**Test pit excavation**
Pit Location.:	**Adjacent to test pit No 1**	Sample Condition:	**Disturbed**
Pavement Pit No.:	KO2	Date Received:	**01/12/2000**

Depth (mm)	Pavement Description
0 - 100	**Asphalt, hotmix, several layers, surface in good condition**
100 - 200	**Silty GRAVEL, fine to medium, GAP20, dense, slightly moist, crushed scoria, reddish brown**
200 -480	**Silty GRAVEL, fine to medium, GAP65, dense, slightly moist**
480	**Top of sub-grade level**
0 - 400	**Sandy silty CLAY, stiff, low plasticity, slightly moist, dark grey and brown**
400 - 700	**Silty CLAY, medium to high plasticity, stiff, slightly moist, light grey and brown**
700 - 1500	**Slightly silty CLAY, stiff to very stiff, medium plasticity, slightly moist, grey mottled orange and brown**
1500	**End of auger**



Basecourse sample recovered at:	N/A	(mm)
Sub-base sample recovered at:	N/A	(mm)
Subgrade sample recovered at:	5 depths	(mm)
Depth from ground surface to: commencement of penetration:	500	(mm)

Density By Nuclear Densometer

	Basecourse	Subgrade
Wet Density (t/m3):	N/A	N/A
Dry Density (t/m3):	N/A	N/A
Water Content (%):	N/A	N/A

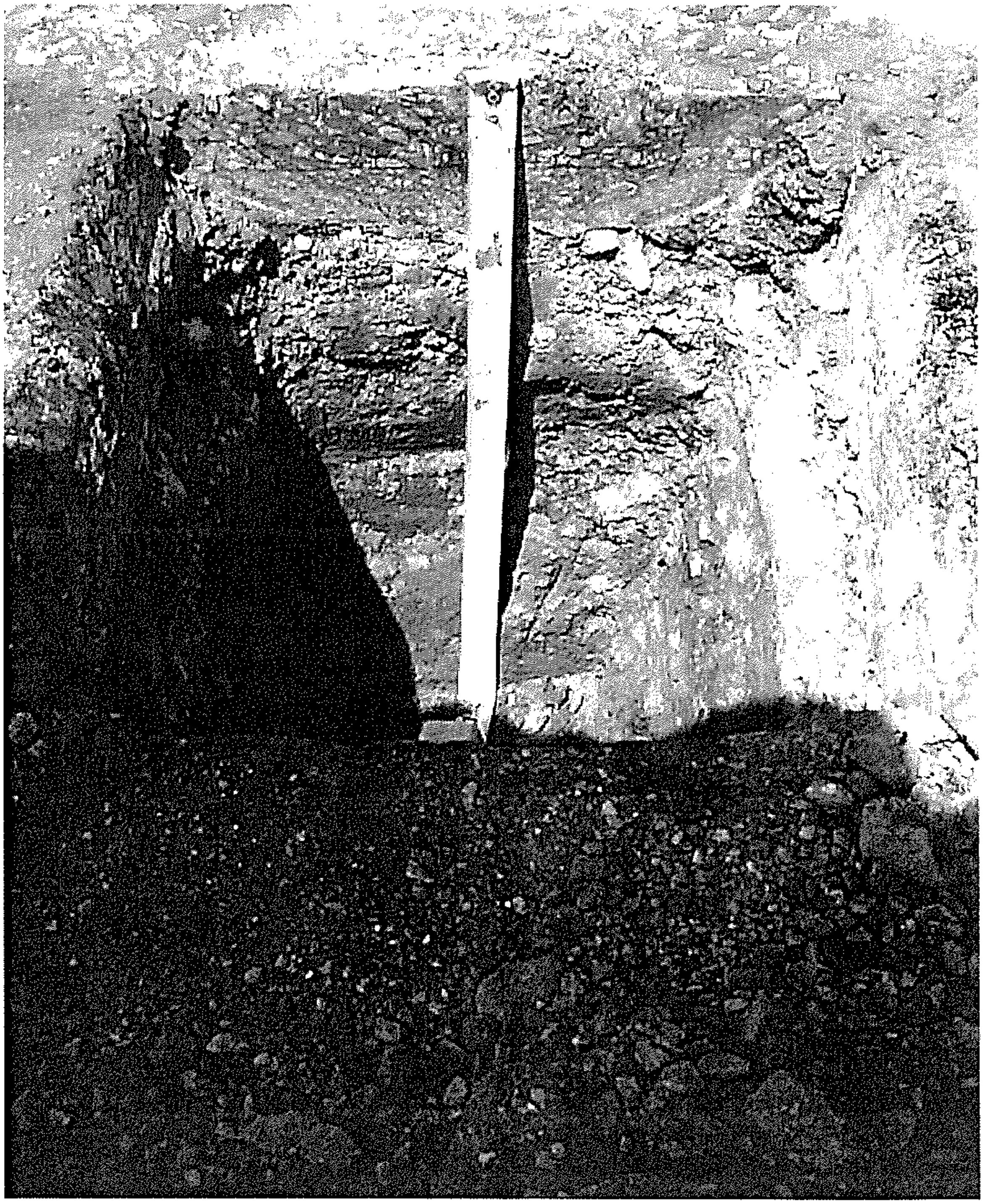
COMMENTS:
The estimated CBR values are based on Figure 5.2 Correlation of Dynamic Cone Penetration and CBR, AUSTROADS (1992) "Pavement Design - A guide to the Structural Design of Road Pavements"

IANZ Accreditation does not apply

Tested By: Iw Date Tested 01/12/00 Checked By: AB Date: 22/01/01

Kohimarama Road, Kohimarama

KO2



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Form No.:	S15b
Form Date:	Oct 1998
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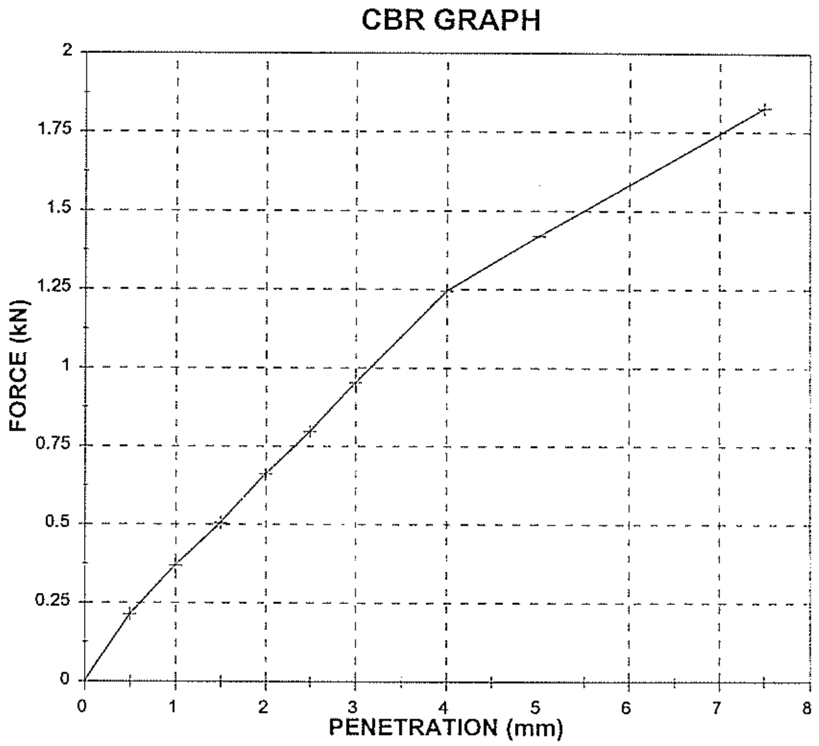
Road.: Kohimarama Road
Page P1 of 52
Site: Test pit KO2
Job Name: BartleyRTU
Job No.: 613836
Location: Opposite No 154
Lane.: Centre of road
Depth: -460 (mm)
Test Method Used: NZS 4402 1986 Test 6.1.3 California Bearing Ratio - In-situ method
NZS 4402 1986 Test 2.1 Determination of the Water Content

CALIFORNIA BEARING RATIO TEST- IN-SITU METHOD

Proving Ring No. : RO300
Proving Ring constant : 0.0778 (kN/div)
Water content: 21.8 (%)
Dial gauge No.: RO253

PENETRATION	FORCE	
(mm)	(div)	(kN)
0.00	0.00	0.00
0.50	2.75	0.21
1.00	4.75	0.37
1.50	6.50	0.51
2.00	8.50	0.66
2.50	10.25	0.80
3.00	12.25	0.95
4.00	16.00	1.24
5.00	18.25	1.42
7.50	23.50	1.83



CBR RESULTS:

2.5 mm		
CORRECTED	(div)	10
FORCE	F (kN)	0.80
CBR (%)	(= F*100/13.2)	6.0
5.0 mm		
CORRECTED	(div)	18
FORCE	F (kN)	1.42
CBR (%)	(= F*100/20)	7.1
FINAL CBR VALUE:		7

Linear Regression is needed (Y/N) ? N
Initial Peneration Reading (mm): 0.00
Surcharge (Kg): 6
Base weight diameter (mm): 150
Rate of penetration by plunger (mm/min): 1/1

COMMENT:
Test performed at 460mm below top of pavement layer

MATERIAL DESCRIPTION:
As per pit log

Tested by: IW Date: 01/12/00 Checked by: AB Date: 22/01/01

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Form No.:	
Form Date:	Nov 1998
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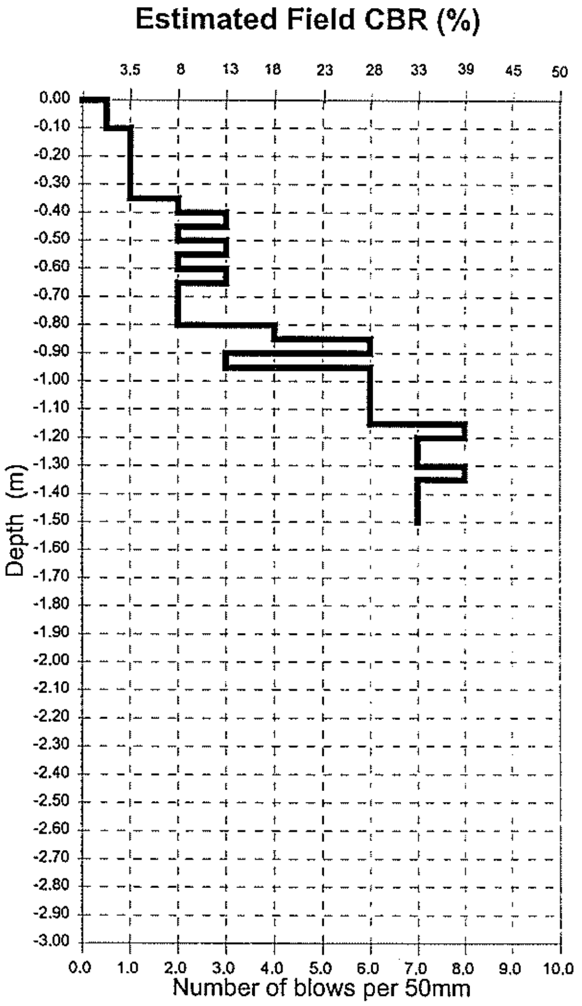
Job Name:	**CBR Investigations**	Job No.:	**613836**	Client Ref.:	**Bartley RTU**
Client:	**Bartley Consultants**	Contractor:	**Geotechnics**		
Test Method Used:	NZS 4402 : 1988 Test 6.5.2	Dynamic Cone Penetrometer			

PAVEMENT INVESTIGATION LOG TEST REPORT

Project:	CBR Investigations	Sampled By:	**IW**
Location:	Blockhouse Bay Road	Date Sampled:	**18/12/2000**
Lane:	Left hand wheel-track	Sampling Method:	**Test pit excavation**
Pit Location.:	Opposite house No163	Sample Condition:	**Disturbed**
Pavement Pit No.:	BB1	Date Received:	**18/12/2000**

Depth (mm)	Pavement Description
0 - 80	**Asphalt, chipseal, grade 3-4, several layers**
80 - 450	**Silty GRAVEL, fine to coarse, GAP100, large scoria aggregate with a silt matrix, very dense, slightly moist**
450	**Top of sub-grade level**
0 - 200	**Clayey SILT, medium plasticity, firm, slightly moist, brown**
200 - 1500	**Slightly clayey SILT, stiff, low to medium plasticity, light brown and light grey**
1500	**End of auger**



Basecourse sample recovered at:	N/A	(mm)
Sub-base sample recovered at:	N/A	(mm)
Subgrade sample recovered at:	5 depths	(mm)
Depth from ground surface to: commencement of penetration:	450	(mm)

Density By Nuclear Densometer

	Basecourse	Subgrade
Wet Density (t/m3):	N/A	N/A
Dry Density (t/m3):	N/A	N/A
Water Content (%):	N/A	N/A

COMMENTS:
The estimated CBR values are based on Figure 5.2 Correlation of Dynamic Cone Penetration and CBR, AUSTROADS (1992) "Pavement Design - A guide to the Structural Design of Road Pavements"

IANZ Accreditation does not apply

Tested By: IW Date Tested 18/12/00 Checked By: AB Date: 22/01/01

Blockhouse Bay Road

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Form No.:	S15b
Form Date:	Oct 1998
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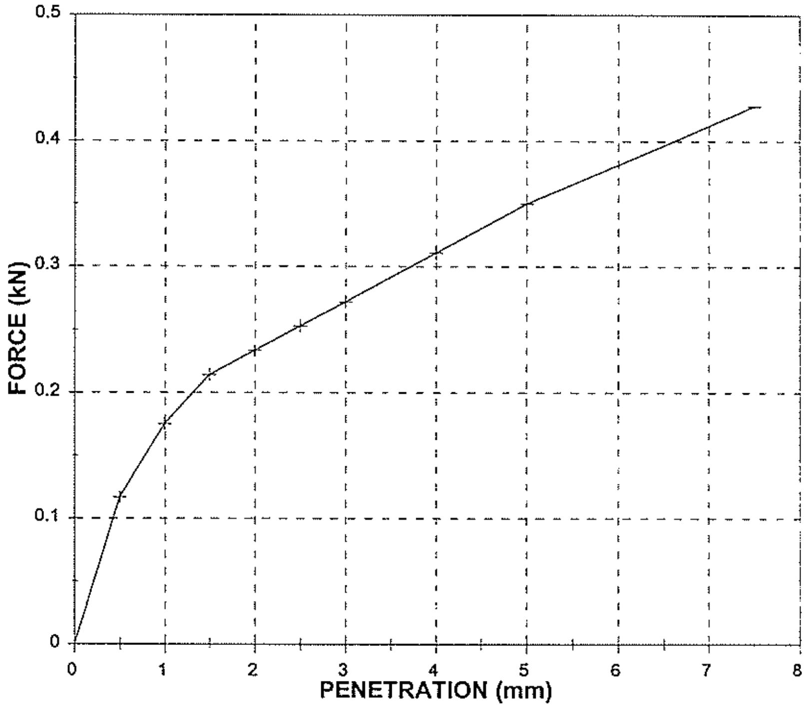
Road.: Blockhouse Bay Road
Page 22 of 52
Site: Test pit BB1
Job Name: BartleyRTU
Job No.: 613836
Location: Opposite House No163
Lane.: Left hand wheel-track
Depth: -450 (mm)
Test Method Used: NZS 4402 1986 Test 6.1.3 California Bearing Ratio - In-situ method
NZS 4402 1986 Test 2.1 Determination of the Water Content

CALIFORNIA BEARING RATIO TEST- IN-SITU METHOD

Proving Ring No. :	RO300		Water content:	35.1	(%)
Proving Ring constant :	0.0778	(kN/div)	Dial gauge No.:	RO253	

PENETRATION	FORCE	
(mm)	(div)	(kN)
0.00	0.00	0.00
0.50	1.50	0.12
1.00	2.25	0.18
1.50	2.75	0.21
2.00	3.00	0.23
2.50	3.25	0.25
3.00	3.50	0.27
4.00	4.00	0.31
5.00	4.50	0.35
7.50	5.50	0.43

CBR GRAPH



CBR RESULTS:

2.5 mm		
CORRECTED	(div)	3
FORCE	F (kN)	0.25
CBR (%)	(= F*100/13.2)	1.9
5.0 mm		
CORRECTED	(div)	5
FORCE	F (kN)	0.35
CBR (%)	(= F*100/20)	1.8
FINAL CBR VALUE:		2

Linear Regression is needed (Y/N) ?	N
Initial Peneration Reading (mm):	0.00
Surcharge (Kg):	6
Base weight diameter (mm):	150
Rate of penetration by plunger (mm/min):	1/1

COMMENT:
Test performed at 450mm below top of pavement layer

MATERIAL DESCRIPTION:
As per pit log

Tested by: IW Date: 18/12/00 Checked by: AB Date: 22/01/01

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Form No.:	
Form Date:	Nov 1998
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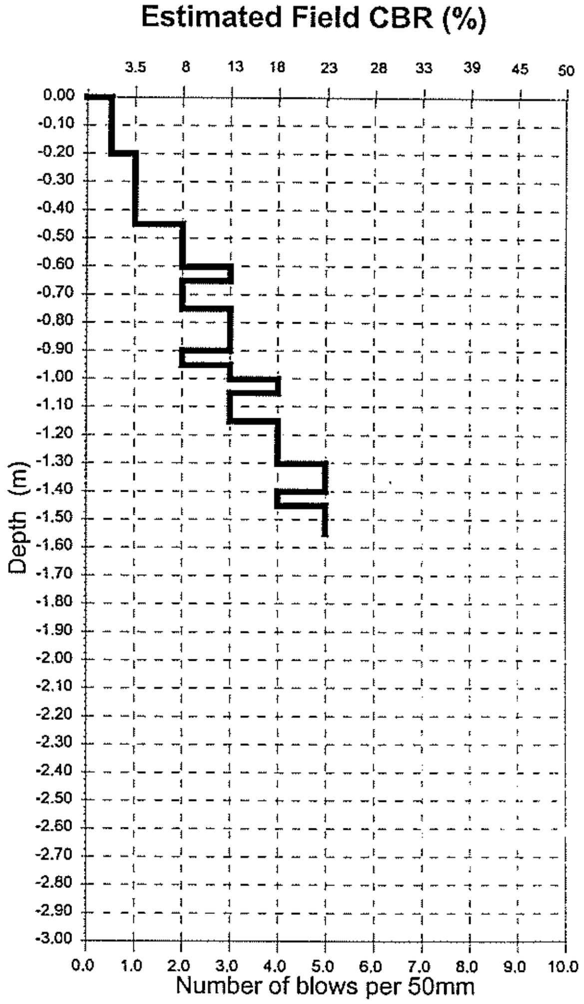
Job Name: CBR Investigations Job No.: 613836 Client Ref.: **Bartley RTU**
Client: Bartley Consultants Contractor: **Geotechnics**
Test Method Used: NZS 4402 : 1988 Test 6.5.2 Dynamic Cone Penetrometer

PAVEMENT INVESTIGATION LOG TEST REPORT

Project:	CBR Investigations	Sampled By:	**IW**
Location:	Blockhouse Bay Road	Date Sampled:	**18/12/2000**
Lane:	Left hand wheel-track	Sampling Method:	**Test pit excavation**
Pit Location.:	Outside house No180	Sample Condition:	**Disturbed**
Pavement Pit No.:	BB3	Date Received:	**18/12/2000**

Depth (mm)	Pavement Description
0 - 70	Asphalt, chipseal, grade 3-4, several layers
70 - 250	Silty GRAVEL, fine to medium, GAP40, dense, slightly moist, well graded
250 - 450	Silty GRAVEL, fine to coarse, GAP100, large scoria aggregate with a silt matrix, very dense, slightly moist
450	Top of sub-grade level
0 - 250	Clayey SILT, medium plasticity, firm to stiff, slightly moist, grey with brown mottles
250 - 1500	Slightly clayey SILT, low to medium plasticity, firm, slightly moist to moist, brown, grey and pink
1500	End of auger



Basecourse sample recovered at:	N/A	(mm)
Sub-base sample recovered at:	N/A	(mm)
Subgrade sample recovered at:	5 depths	(mm)
Depth from ground surface to: commencement of penetration:	450	(mm)

Density By Nuclear Densometer

	Basecourse	Subgrade
Wet Density (t/m3):	N/A	N/A
Dry Density (t/m3):	N/A	N/A
Water Content (%):	N/A	N/A

COMMENTS:
The estimated CBR values are based on Figure 5.2 Correlation of Dynamic Cone Penetration and CBR, AUSTROADS (1992) "Pavement Design - A guide to the Structural Design of Road Pavements"

IANZ Accreditation does not apply

Tested By: Date Tested 18/12/00 Checked By: AB Date: 22/01/01

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Form No.:	S15b
Form Date:	Oct 1998
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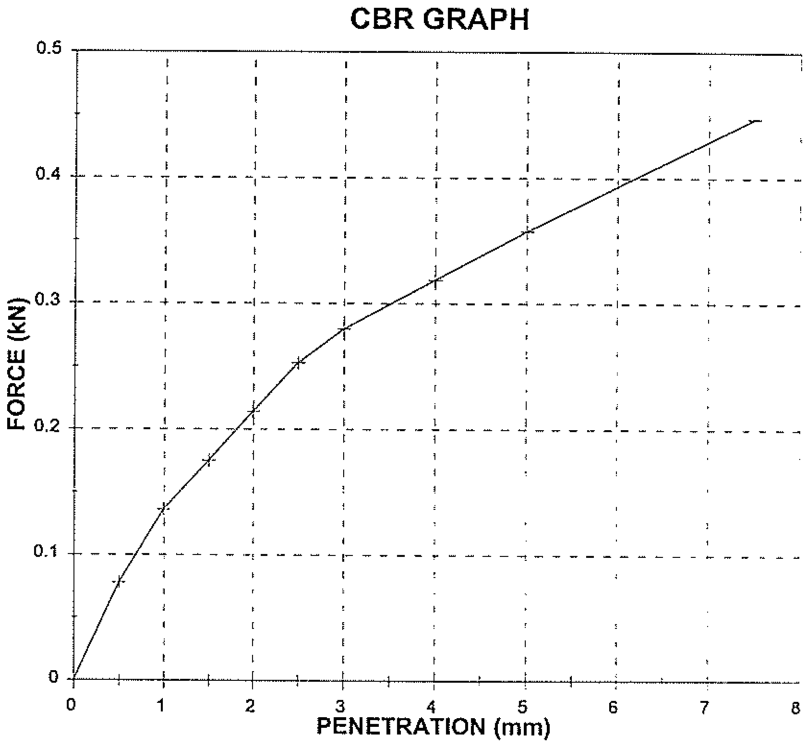
Road.: Blockhouse Bay Road
Page 24 of 52
Site: Test pit BB3
Job Name: BartleyRTU
Job No.: 613836
Location: Outside House No180
Lane.: Left hand wheel-track
Depth: -450 (mm)
Test Method Used: NZS 4402 1986 Test 6.1.3 California Bearing Ratio - In-situ method
NZS 4402 1986 Test 2.1 Determination of the Water Content

CALIFORNIA BEARING RATIO TEST- IN-SITU METHOD

Proving Ring No. : RO300
Proving Ring constant : 0.0778 (kN/div)
Water content: 51.4 (%)
Dial gauge No.: RO253

PENETRATION (mm)	FORCE (div)	FORCE (kN)
0.00	0.00	0.00
0.50	1.00	0.08
1.00	1.75	0.14
1.50	2.25	0.18
2.00	2.75	0.21
2.50	3.25	0.25
3.00	3.60	0.28
4.00	4.10	0.32
5.00	4.60	0.36
7.50	5.75	0.45



CBR RESULTS:

2.5 mm		
CORRECTED FORCE	(div)	3
	F (kN)	0.25
CBR (%)	(= F*100/13.2)	1.9
5.0 mm		
CORRECTED FORCE	(div)	5
	F (kN)	0.36
CBR (%)	(= F*100/20)	1.8
FINAL CBR VALUE:		2

Linear Regression is needed (Y/N) ? N
Initial Peneration Reading (mm): 0.00
Surcharge (Kg): 6
Base weight diameter (mm): 150
Rate of penetration by plunger (mm/min): 1/1

COMMENT:
Test performed at 450mm below top of pavement layer

MATERIAL DESCRIPTION:
As per pit log

Tested by: IW
Date: 18/12/00
Checked by: AB
Date: 22/01/01

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Form No.:	
Form Date:	Nov 1998
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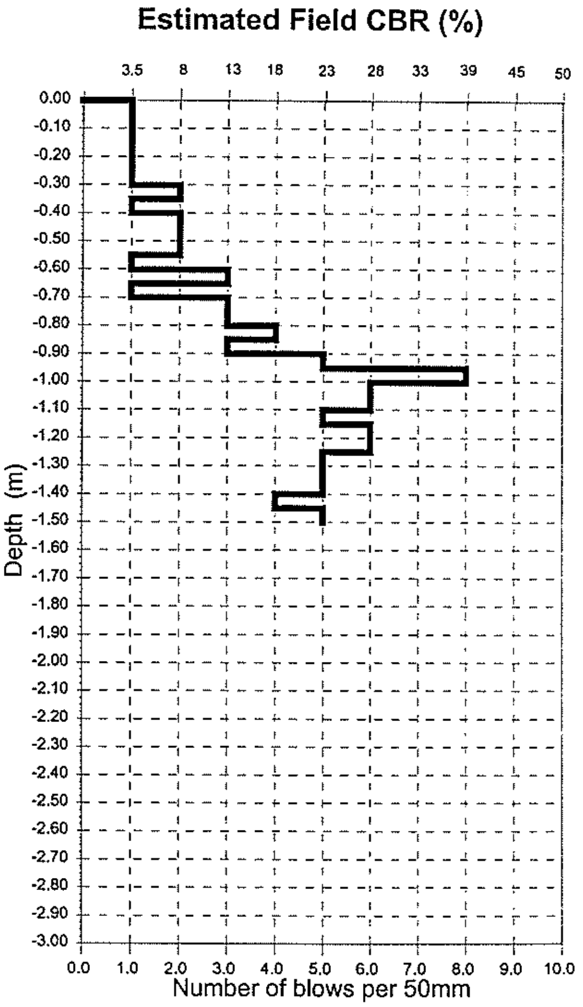
Job Name: CBR Investigations Job No.: **613836** Client Ref.: **Bartley RTU**
Client: Bartley Consultants Contractor: **Geotechnics**
Test Method Used: NZS 4402 : 1988 Test 6.5.2 Dynamic Cone Penetrometer

PAVEMENT INVESTIGATION LOG TEST REPORT

Project:	CBR Investigations	Sampled By:	**IW**
Location:	Blockhouse Bay Road	Date Sampled:	**18/12/2000**
Lane:	Left hand wheel-track	Sampling Method:	**Test pit excavation**
Pit Location.:	Opposite house No175	Sample Condition:	**Disturbed**
Pavement Pit No.:	BB5	Date Received:	**18/12/2000**

Depth (mm)	Pavement Description
0 - 70	**Asphalt, chipseal, grade 3-4, several layers**
70 - 200	**Silty GRAVEL, fine to medium, GAP40, dense to very dense, slightly moist, well graded**
200 - 400	**Silty GRAVEL, fine to coarse, GAP100, large scoria aggregate with a silt matrix, very dense, slightly moist**
400	**Top of sub-grade level**
0 - 200	**Clayey SILT, medium to high plasticity, firm, slightly moist, grey**
200 - 1500	**Slightly clayey SILT, low to medium plasticity, firm, slightly moist to moist, brown, grey and pink**
1500	**End of auger**



Basecourse sample recovered at:	N/A	(mm)
Sub-base sample recovered at:	N/A	(mm)
Subgrade sample recovered at:	5 depths	(mm)
Depth from ground surface to: commencement of penetration:	400	(mm)

Density By Nuclear Densometer

	Basecourse	Subgrade
Wet Density (t/m3):	N/A	N/A
Dry Density (t/m3):	N/A	N/A
Water Content (%):	N/A	N/A

COMMENTS:
The estimated CBR values are based on Figure 5.2 Correlation of Dynamic Cone Penetration and CBR, AUSTROADS (1992) "Pavement Design - A guide to the Structural Design of Road Pavements"

IANZ Accreditation does not apply

Tested By: Date Tested 18/12/00 Checked By: AB Date: 22/01/01

Blockhouse Bay Road

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Form No.:	S15b
Form Date:	Oct 1998
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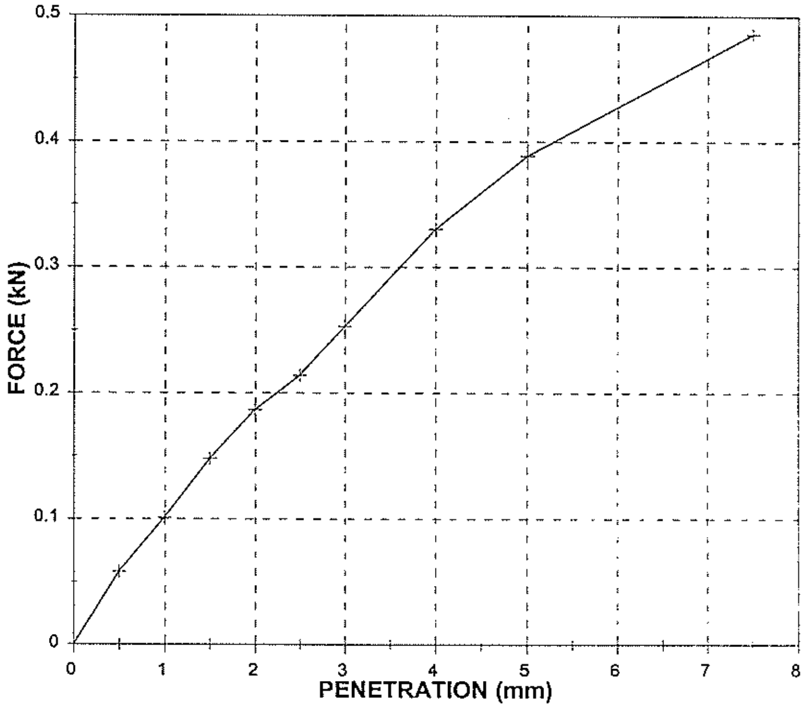
Road.: Blockhouse Bay Road
Page 27 of 52
Site: Test pit BB5
Job Name: BartleyRTU
Job No.: 613836
Location: Opposite House No175
Lane.: Left hand wheel-track
Depth: -400 (mm)
Test Method Used: NZS 4402 1986 Test 6.1.3 California Bearing Ratio - In-situ method
NZS 4402 1986 Test 2.1 Determination of the Water Content

CALIFORNIA BEARING RATIO TEST- IN-SITU METHOD

Proving Ring No. : RO300
Proving Ring constant : 0.0778 (kN/div)
Water content: 58.9 (%)
Dial gauge No.: RO253

PENETRATION	FORCE	
(mm)	(div)	(kN)
0.00	0.00	0.00
0.50	0.75	0.06
1.00	1.30	0.10
1.50	1.90	0.15
2.00	2.40	0.19
2.50	2.75	0.21
3.00	3.25	0.25
4.00	4.25	0.33
5.00	5.00	0.39
7.50	6.25	0.49

CBR GRAPH



CBR RESULTS:

2.5 mm		
CORRECTED	(div)	3
FORCE	F (kN)	0.21
CBR (%)	(= F*100/13.2)	1.6
5.0 mm		
CORRECTED	(div)	5
FORCE	F (kN)	0.39
CBR (%)	(= F*100/20)	1.9
FINAL CBR VALUE:		2

Linear Regression is needed (Y/N) ? N
Initial Peneration Reading (mm): 0.00
Surcharge (Kg): 6
Base weight diameter (mm): 150
Rate of penetration by plunger (mm/min): 1/1

COMMENT:
Test performed at 450mm below top of pavement layer

MATERIAL DESCRIPTION:
As per pit log

Tested by: IW Date: 18/12/00 Checked by: AB Date: 22/01/01

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Form No.:	
Form Date:	Nov 1998
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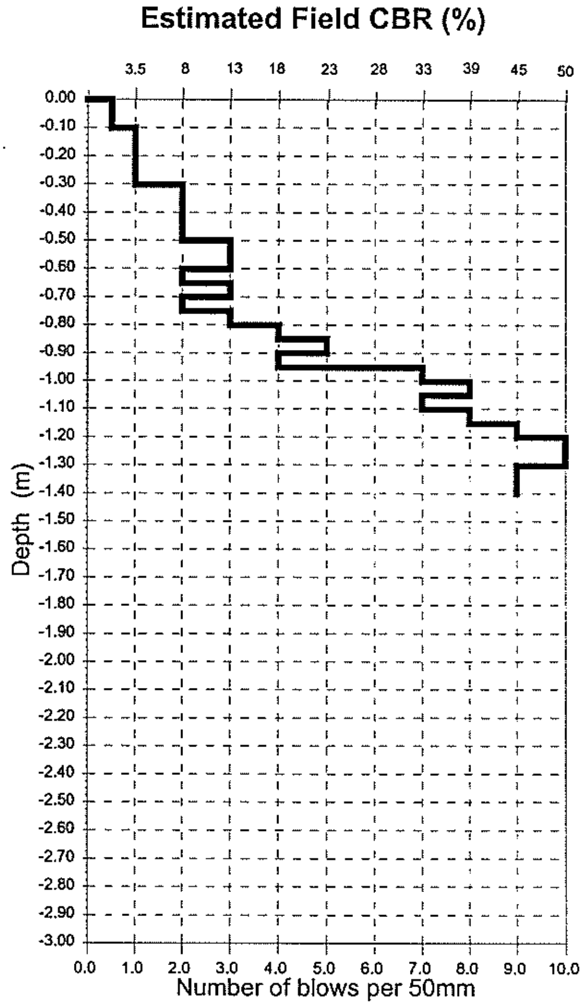
Job Name: CBR Investigations Job No.: **613836** Client Ref.: **Bartley RTU**
Client: Bartley Consultants Contractor: **Geotechnics**
Test Method Used: NZS 4402 : 1988 Test 6.5.2 Dynamic Cone Penetrometer

PAVEMENT INVESTIGATION LOG TEST REPORT

Project:	CBR Investigations	Sampled By:	**IW**
Location:	Blockhouse Bay Road	Date Sampled:	**14/12/2000**
Lane:	Centre of the road	Sampling Method:	**Test pit excavation**
Pit Location.:	Adjacent to pit No1	Sample Condition:	**Disturbed**
Pavement Pit No.:	BB2	Date Received:	**14/12/2000**

Depth (mm)	Pavement Description
0 - 80	**Asphalt, chipseal, grade 3-4, several layers**
80 - 200	**Silty GRAVEL, fine to medium, GAP40, dense to very dense, bitumen impregnated, slightly moist**
200 - 450	**Very silty GRAVEL, GAP100, fine to very coarse, very dense, dry, large scoria aggregate with a silt matrix**
450	**Top of sub-grade**
0 - 250	**Silty CLAY, medium to high plasticity, firm, slightly moist, greenish grey**
250 - 750	**Clayey SILT, medium plasticity, firm to stiff, slightly moist, light grey and light brown**
750 - 1500	**Slightly clayey SILT, low to medium plasticity, stiff to very stiff, slightly moist, light grey mottled light brown**
1500	**End of auger**



Basecourse sample recovered at:	N/A	(mm)
Sub-base sample recovered at:	N/A	(mm)
Subgrade sample recovered at:	5 depths	(mm)
Depth from ground surface to:	450	(mm)
commencement of penetration:		

Density By Nuclear Densometer

	Basecourse	Subgrade
Wet Density (t/m3):	N/A	N/A
Dry Density (t/m3):	N/A	N/A
Water Content (%):	N/A	N/A

COMMENTS:
The estimated CBR values are based on Figure 5.2 Correlation of Dynamic Cone Penetration and CBR, AUSTROADS (1992) "Pavement Design - A guide to the Structural Design of Road Pavements"

IANZ Accreditation does not apply

Tested By: IW Date Tested 14/12/00 Checked By: AR Date: 22/01/01

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Form No.:	S15b
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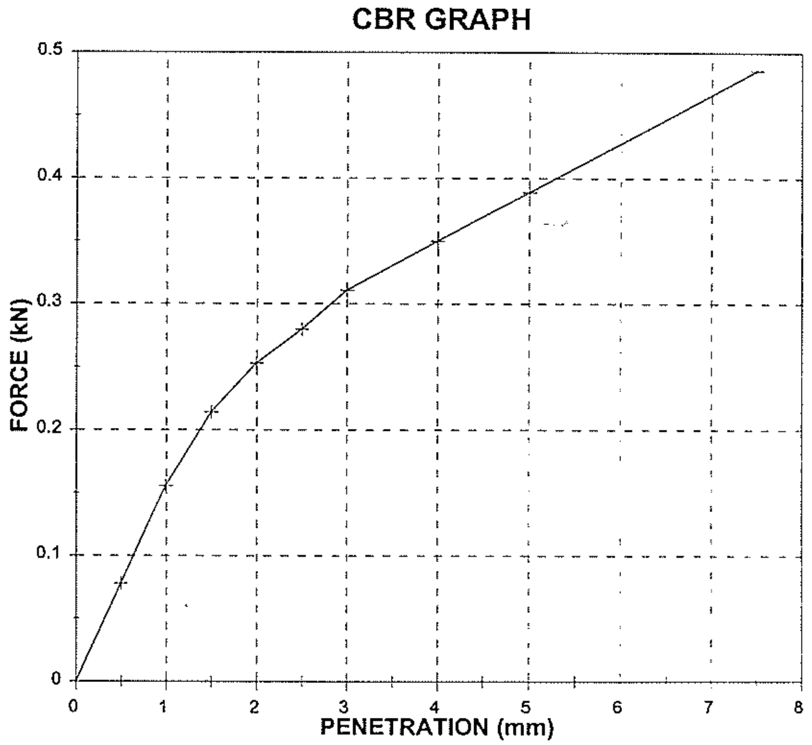
Road.: Blockhouse Bay Road
Page 29 of 52
Site: Test pit BB2
Job Name: BartleyRTU
Job No.: 613836
Location: Adjacent to pit No1
Lane.: Centre of the road
Depth: -450 (mm)
Test Method Used: NZS 4402 1986 Test 6.1.3 California Bearing Ratio - In-situ method
NZS 4402 1986 Test 2.1 Determination of the Water Content

CALIFORNIA BEARING RATIO TEST- IN-SITU METHOD

Proving Ring No. : RO300
Proving Ring constant : 0.0778 (kN/div)
Water content: 27.7 (%)
Dial gauge No.: RO253

PENETRATION (mm)	FORCE (div)	 (kN)
0.00	0.00	0.00
0.50	1.00	0.08
1.00	2.00	0.16
1.50	2.75	0.21
2.00	3.25	0.25
2.50	3.60	0.28
3.00	4.00	0.31
4.00	4.50	0.35
5.00	5.00	0.39
7.50	6.25	0.49



CBR RESULTS:

2.5 mm		
CORRECTED	(div)	4
FORCE	F (kN)	0.28
CBR (%)	(= F*100/13.2)	2.1
5.0 mm		
CORRECTED	(div)	5
FORCE	F (kN)	0.39
CBR (%)	(= F*100/20)	1.9
FINAL CBR VALUE:		2

Linear Regression is needed (Y/N) ? N
Initial Peneration Reading (mm): 0.00
Surcharge (Kg): 6
Base weight diameter (mm): 150
Rate of penetration by plunger (mm/min): 1/1

COMMENT:
Test performed at 450mm below top of pavement layer

MATERIAL DESCRIPTION:
As per pit log

Tested by: IW Date: 14/12/00 Checked by: AB Date: 22/01/01

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Form No.:	
Form Date:	Nov 1998
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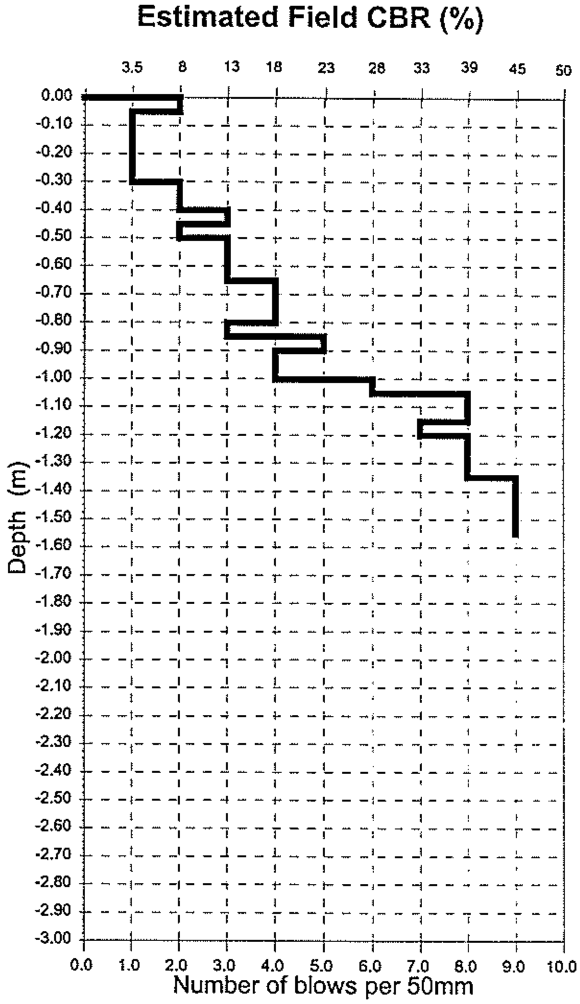
Job Name: CBR Investigations Job No.: **613836** Client Ref.: **Bartley RTU**
Client: Bartley Consultants Contractor: **Geotechnics**
Test Method Used: NZS 4402 : 1988 Test 6.5.2 Dynamic Cone Penetrometer

PAVEMENT INVESTIGATION LOG TEST REPORT

Project:	CBR Investigations	Sampled By:	**IW**
Location:	Blockhouse Bay Road	Date Sampled:	**14/12/2000**
Lane:	Centre of the road	Sampling Method:	**Test pit excavation**
Pit Location.:	Adjacent to pit No2	Sample Condition:	**Disturbed**
Pavement Pit No.:	BB4	Date Received:	**14/12/2000**

Depth (mm)	Pavement Description
0 - 90	Asphalt, chipseal, grade 3-4, **several layers**
90 - 200	Silty GRAVEL, fine to medium, **GAP40, dense to very** dense, bitumen impregnated, **slightly moist**
200 - 400	Silty Gravel, fine to medium, **GAP65, very dense,** slightly moist
400	**Top of sub-grade level**
0 - 150	**Silty CLAY, medium to high plasticity, firm, slightly moist, greenish grey**
150 - 450	**Clayey SILT, medium plasticity, firm to stiff, slightly moist, light grey and light brown**
450 - 1500	**Slightly clayey SILT, low to medium plasticity, stiff to very stiff, slightly moist, light grey mottled light brown**
1500	**End of auger**



Basecourse sample recovered at:	N/A	(mm)
Sub-base sample recovered at:	N/A	(mm)
Subgrade sample recovered at:	5 depths	(mm)
Depth from ground surface to:	400	(mm)
commencement of penetration:		

Density By Nuclear Densometer

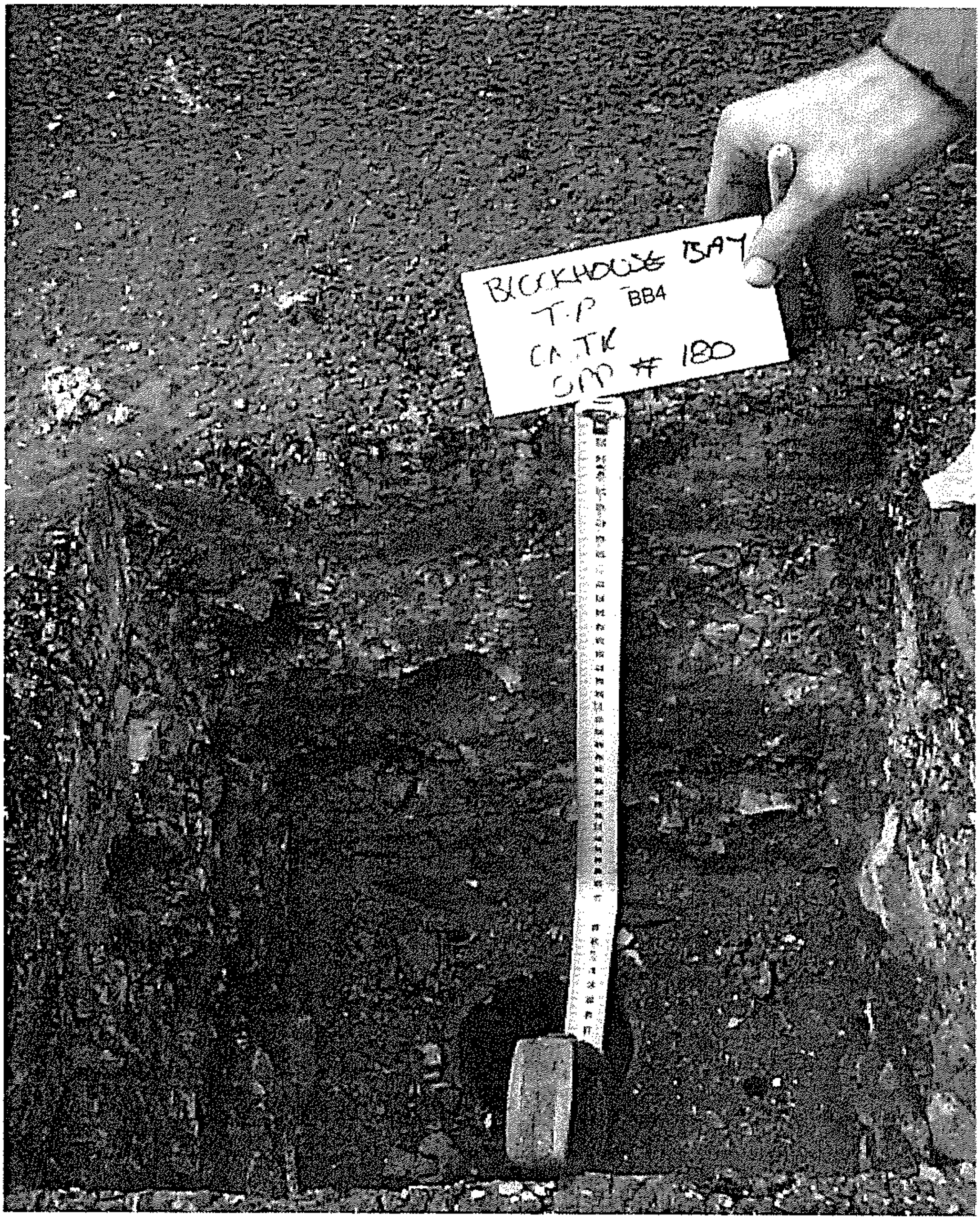
	Basecourse	Subgrade
Wet Density (t/m3):	N/A	N/A
Dry Density (t/m3):	N/A	N/A
Water Content (%):	N/A	N/A

COMMENTS:
The estimated CBR values are based on Figure 5.2 Correlation of Dynamic Cone Penetration and CBR, AUSTROADS (1992) "Pavement Design - A guide to the Structural Design of Road Pavements"

IANZ Accreditation does not apply

Tested By: IWS Date Tested 14/12/00 Checked By: AB Date: 22/01/01

Blockhouse Bay Road, Blockhouse Bay



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Form No.:	S15b
Form Date:	Oct 1998
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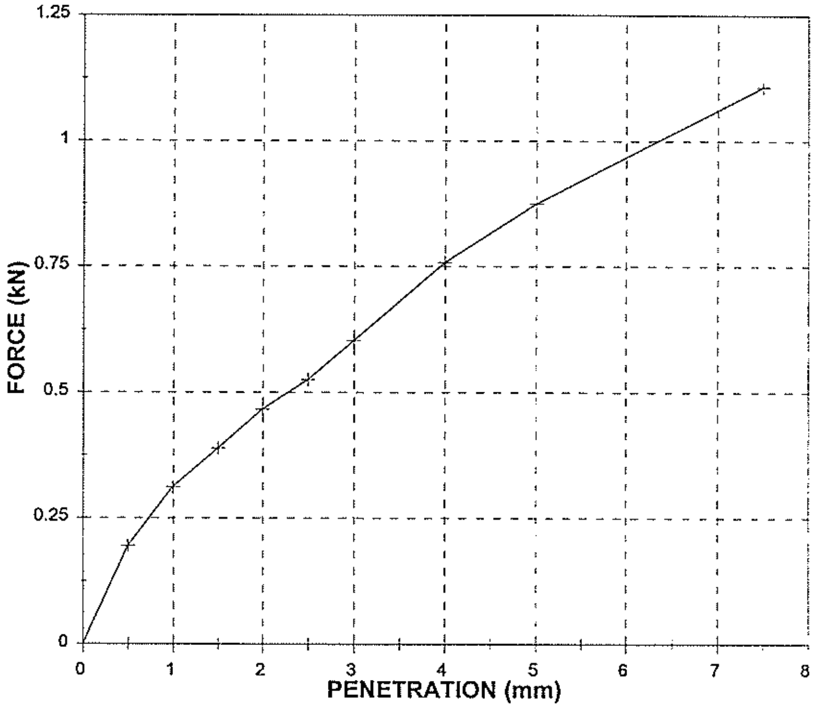
Road.: Blockhouse Bay Road
Page 32 of 52
Site: Test pit BB4
Job Name: BartleyRTU
Job No.: 613836
Location: Adjacent to pit No2
Lane.: Centre of the road
Depth: -400 (mm)
Test Method Used: NZS 4402 1986 Test 6.1.3 California Bearing Ratio - In-situ method
NZS 4402 1986 Test 2.1 Determination of the Water Content

CALIFORNIA BEARING RATIO TEST- IN-SITU METHOD

Proving Ring No. : RO300
Proving Ring constant : 0.0778 (kN/div)
Water content: 34.4 (%)
Dial gauge No.: RO253

PENETRATION	FORCE	
(mm)	(div)	(kN)
0.00	0.00	0.00
0.50	2.50	0.19
1.00	4.00	0.31
1.50	5.00	0.39
2.00	6.00	0.47
2.50	6.75	0.53
3.00	7.75	0.60
4.00	9.75	0.76
5.00	11.25	0.88
7.50	14.25	1.11

CBR GRAPH



CBR RESULTS:

2.5 mm		
CORRECTED	(div)	7
FORCE	F (kN)	0.53
CBR (%)	(= F*100/13.2)	4.0
5.0 mm		
CORRECTED	(div)	11
FORCE	F (kN)	0.88
CBR (%)	(= F*100/20)	4.4
FINAL CBR VALUE:		4.5

Linear Regression is needed (Y/N) ? N
Initial Peneration Reading (mm): 0.00
Surcharge (Kg): 6
Base weight diameter (mm): 150
Rate of penetration by plunger (mm/min): 1/1

COMMENT:
Test performed at 400mm below top of pavement layer

MATERIAL DESCRIPTION:
As per pit log

Tested by: IW Date: 14/12/00 Checked by: AB Date: 22/01/01

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Form No.:	
Form Date:	Nov 1998
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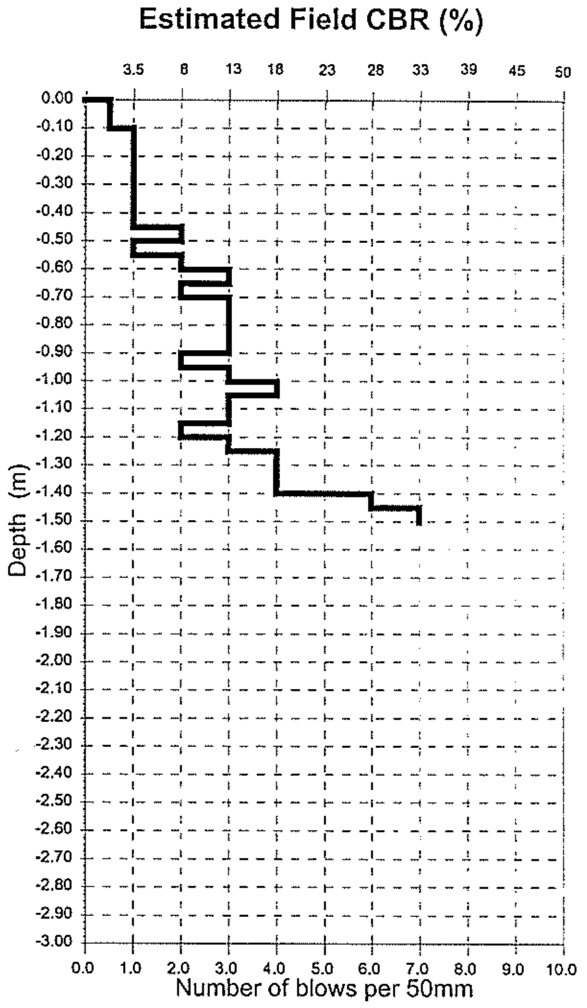
Job Name:	**CBR Investigations**	Job No.:	**613836**	Client Ref.:	**Bartley RTU**
Client:	**Bartley Consultants**	Contractor:	**Geotechnics**		
Test Method Used:	NZS 4402 : 1988 Test 6.5.2	Dynamic Cone Penetrometer			

PAVEMENT INVESTIGATION LOG TEST REPORT

Project:	**CBR Investigations**	Sampled By:	**IW**
Location:	**Blockhouse Bay Road**	Date Sampled:	**14/12/2000**
Lane:	**Centre of the road**	Sampling Method:	**Test pit excavation**
Pit Location.:	**Adjacent to pit No3**	Sample Condition:	**Disturbed**
Pavement Pit No.:	BB6	Date Received:	**14/12/2000**

Depth (mm)	Pavement Description
0 - 70	**Asphalt, chipseal, grade 3-4, several layers**
70 - 200	**Silty GRAVEL, fine to medium, GAP40, dense to very dense, slightly moist**
200 - 450	**Silty Gravel, fine to coarse, GAP100, very dense, slightly moist, large scoria aggregate with a silt matrix**
450	**Top of sub-grade level**
0 - 250	**Clayey SILT, firm, medium to high plasticity, slightly moist, grey**
250 - 1500	**Slightly clayey SILT, low to medium plasticity, stiff to very stiff, slightly moist, light grey mottled light brown**
1500	**End of auger**



Basecourse sample recovered at:	N/A	(mm)
Sub-base sample recovered at:	N/A	(mm)
Subgrade sample recovered at:	5 depths	(mm)
Depth from ground surface to: commencement of penetration:	450	(mm)

Density By Nuclear Densometer

	Basecourse	Subgrade
Wet Density (t/m3):	N/A	N/A
Dry Density (t/m3):	N/A	N/A
Water Content (%):	N/A	N/A

COMMENTS:
The estimated CBR values are based on Figure 5.2 Correlation of Dynamic Cone Penetration and CBR, AUSTROADS (1992) "Pavement Design - A guide to the Structural Design of Road Pavements"

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Tested By:	IW	Date Tested	14/12/00	Checked By:	AB	Date:	22/01/01

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Form Date:	Oct 1998
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Road.: Blockhouse Bay Road

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Site: Test pit BB6 Job Name: BartleyRTU Job No.: 613836

Location: Adjacent to pit No3 Lane.: Centre of the road Depth: -450 (mm)

Test Method Used: NZS 4402 1986 Test 6.1.3 California Bearing Ratio - In-situ method
NZS 4402 1986 Test 2.1 Determination of the Water Content

CALIFORNIA BEARING RATIO TEST- IN-SITU METHOD

Proving Ring No. : RO300

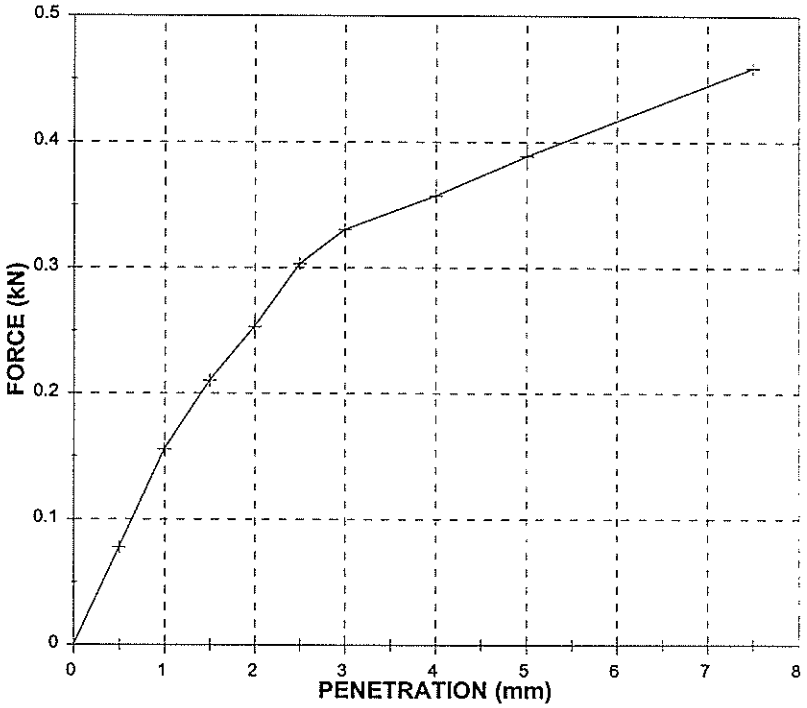
Proving Ring constant : 0.0778 (kN/div)

Water content: 57.3 (%)

Dial gauge No.: RO253

PENETRATION	FORCE	
(mm)	(div)	(kN)
0.00	0.00	0.00
0.50	1.00	0.08
1.00	2.00	0.16
1.50	2.70	0.21
2.00	3.25	0.25
2.50	3.90	0.30
3.00	4.25	0.33
4.00	4.60	0.36
5.00	5.00	0.39
7.50	5.90	0.46

CBR GRAPH



CBR RESULTS:

2.5 mm		
CORRECTED FORCE	(div)	4
	F (kN)	0.30
CBR (%)	(= F*100/13.2)	2.3
5.0 mm		
CORRECTED FORCE	(div)	5
	F (kN)	0.39
CBR (%)	(= F*100/20)	1.9
FINAL CBR VALUE:		2.5

Linear Regression is needed (Y/N) ?	N
Initial Peneration Reading (mm):	0.00
Surcharge (Kg):	6
Base weight diameter (mm):	150
Rate of penetration by plunger (mm/min):	1/1

COMMENT:

Test performed at 450mm below top of pavement layer

MATERIAL DESCRIPTION:

As per pit log

Tested by: IW Date: 14/12/00 Checked by: AB Date: 22/01/01

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Form Date:	Nov 1998
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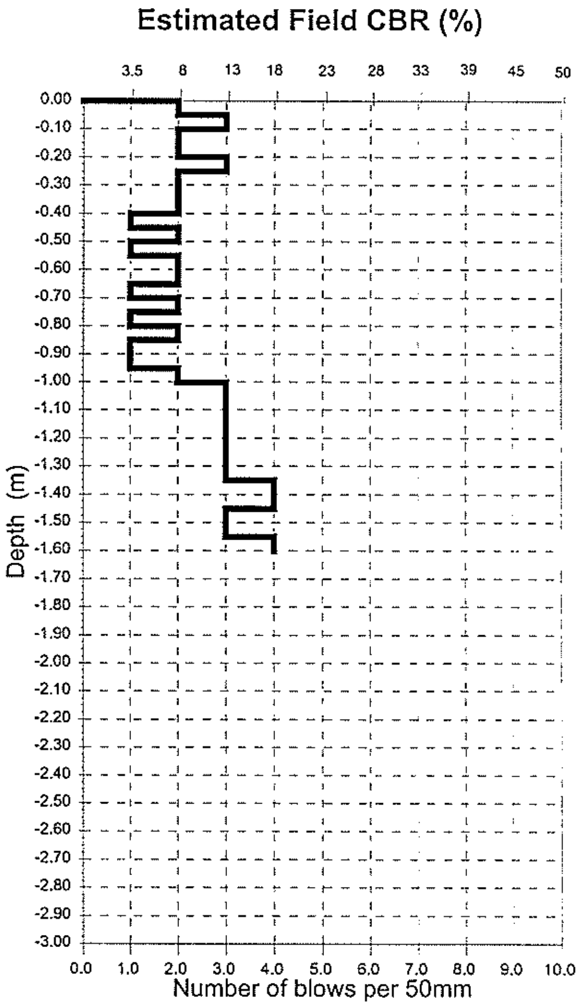
Job Name: **CBR Investigations** Job No.: **613836** Client Ref.: **Bartley RTU**
Client: **Bartley Consultants** Contractor: **Geotechnics**
Test Method Used: NZS 4402 : 1988 Test 6.5.2 Dynamic Cone Penetrometer

PAVEMENT INVESTIGATION LOG TEST REPORT

Project:	**CBR Investigations**	Sampled By:	**IW**
Location:	**Bristol Road**	Date Sampled:	**6/12/2000**
Lane:	**Left hand wheel-track**	Sampling Method:	**Test pit excavation**
Pit Location.:	**42m from driveway at house No2**	Sample Condition:	**Disturbed**
Pavement Pit No.:	BR1	Date Received:	**6/12/2000**

Depth (mm)	Pavement Description
0 - 25	**Asphalt, chipseal, grade 3-4, fairly good condition**
25 - 150	**Silty GRAVEL, fine to medium, GAP40, andesite, dense to very dense, slightly moist, possibly stabilised**
150	**Top of sub-grade level**
0 - 200	**SILT, stiff, slightly moist, low plasticity, light orangy brown**
200 - 700	**Slightly clayey SILT, low to medium plasticity, firm, slightly moist, orangy brown**
700 - 1500	**Clayey SILT, low to medium plasticity, firm, slightly moist, light brown with orange and grey mottles**
1500	**End of auger**



Basecourse sample recovered at:	N/A	(mm)
Sub-base sample recovered at:	N/A	(mm)
Subgrade sample recovered at:	5 depths	(mm)
Depth from ground surface to: commencement of penetration:	200	(mm)

Density By Nuclear Densometer

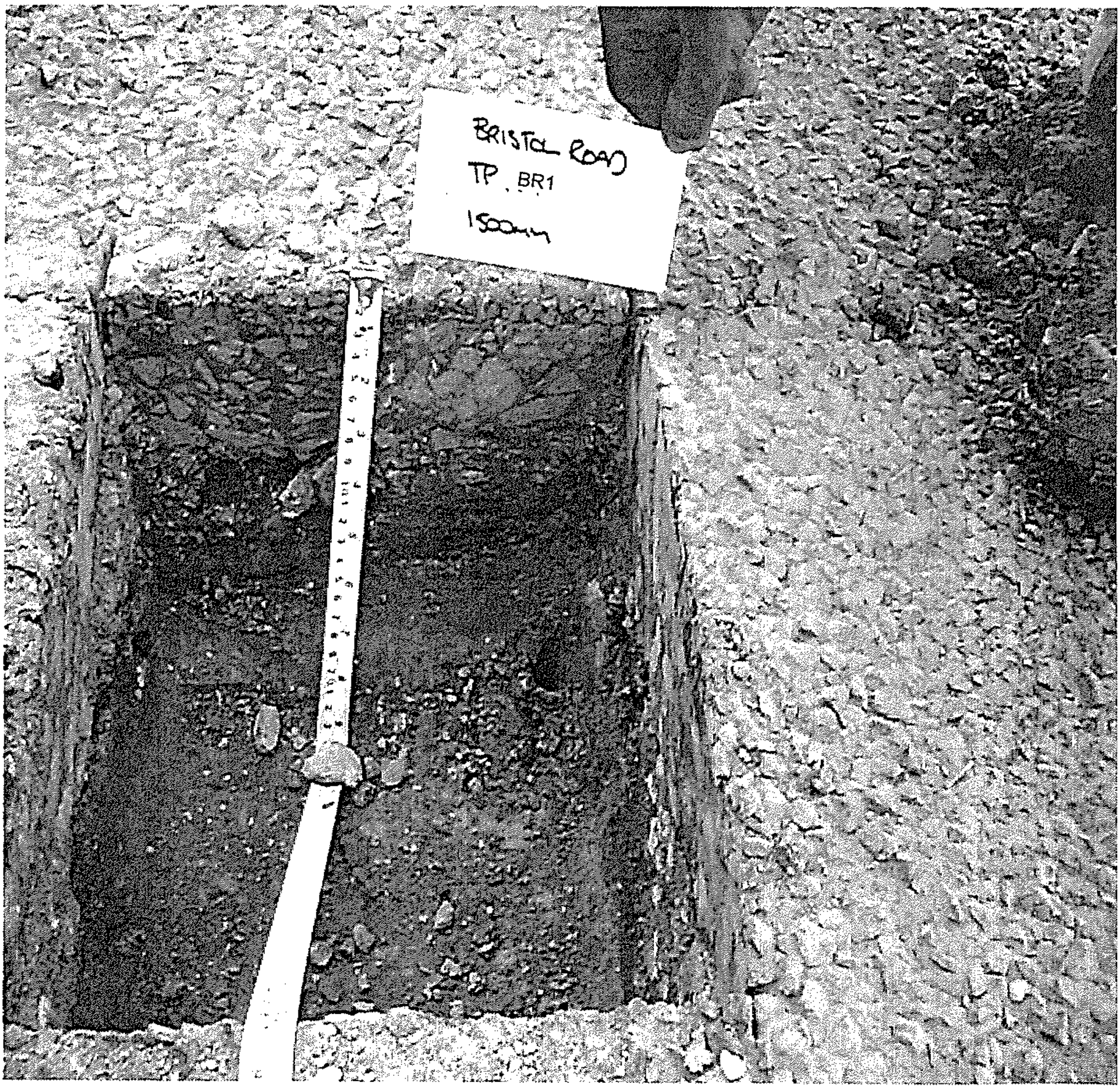
	Basecourse	Subgrade
Wet Density (t/m3):	N/A	N/A
Dry Density (t/m3):	N/A	N/A
Water Content (%):	N/A	N/A

COMMENTS:
The estimated CBR values are based on Figure 5.2 Correlation of Dynamic Cone Penetration and CBR, AUSTROADS (1992) "Pavement Design - A guide to the Structural Design of Road Pavements"

IANZ Accreditation does not apply

Tested By: Date Tested 6/12/00 Checked By: AR Date: 22/01/01

Bristol Road, Whenuapai



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Form No.:	S15b
Form Date:	Oct 1998
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Road.: Bristol Road
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Site: Test pit BR1
Job Name: BartleyRTU
Job No.: 613836

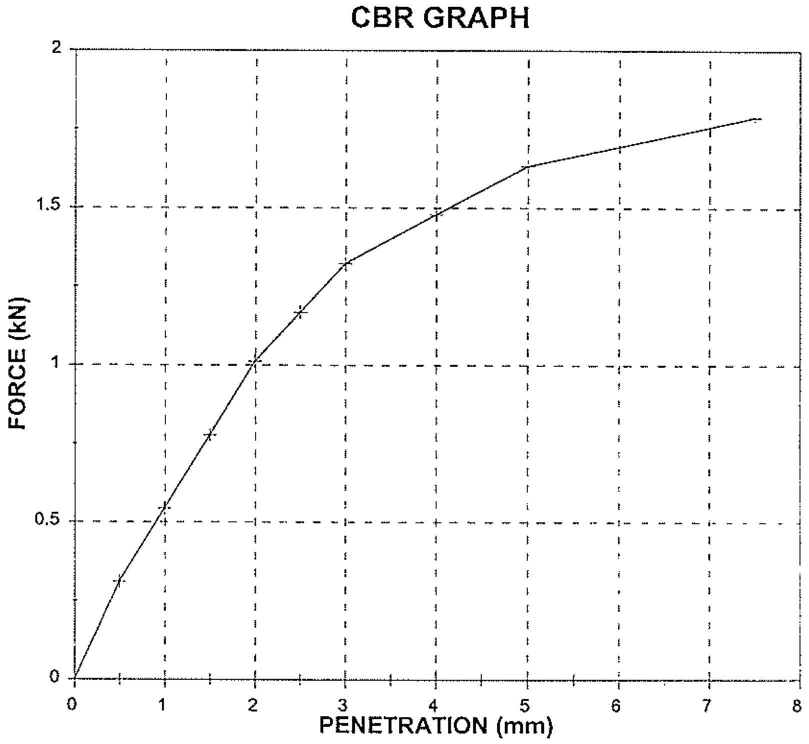
Location: 42m from house No 2
Lane.: Left hand wheel-track
Depth: -200 (mm)

Test Method Used: NZS 4402 1986 Test 6.1.3 California Bearing Ratio - In-situ method
NZS 4402 1986 Test 2.1 Determination of the Water Content

CALIFORNIA BEARING RATIO TEST- IN-SITU METHOD

Proving Ring No. : RO300
Proving Ring constant : 0.0778 (kN/div)
Water content: 59.6 (%)
Dial gauge No.: RO253

PENETRATION	FORCE	
(mm)	(div)	(kN)
0.00	0.00	0.00
0.50	4.00	0.31
1.00	7.00	0.54
1.50	10.00	0.78
2.00	13.00	1.01
2.50	15.00	1.17
3.00	17.00	1.32
4.00	19.00	1.48
5.00	21.00	1.63
7.50	23.00	1.79



CBR RESULTS:

2.5 mm		
CORRECTED FORCE	(div)	15
	F (kN)	1.17
CBR (%)	(= F*100/13.2)	8.8
5.0 mm		
CORRECTED FORCE	(div)	21
	F (kN)	1.63
CBR (%)	(= F*100/20)	8.2
FINAL CBR VALUE:		9

Linear Regression is needed (Y/N) ? N
Initial Peneration Reading (mm): 0.00
Surcharge (Kg): 6
Base weight diameter (mm): 150
Rate of penetration by plunger (mm/min): 1/1

COMMENT:
Test performed at 200mm below top of pavement layer

MATERIAL DESCRIPTION:
As per pit log

Tested by: IW
Date: 6/12/00
Checked by: AB
Date: 22/01/01

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Form No.:	
Form Date:	Nov 1998
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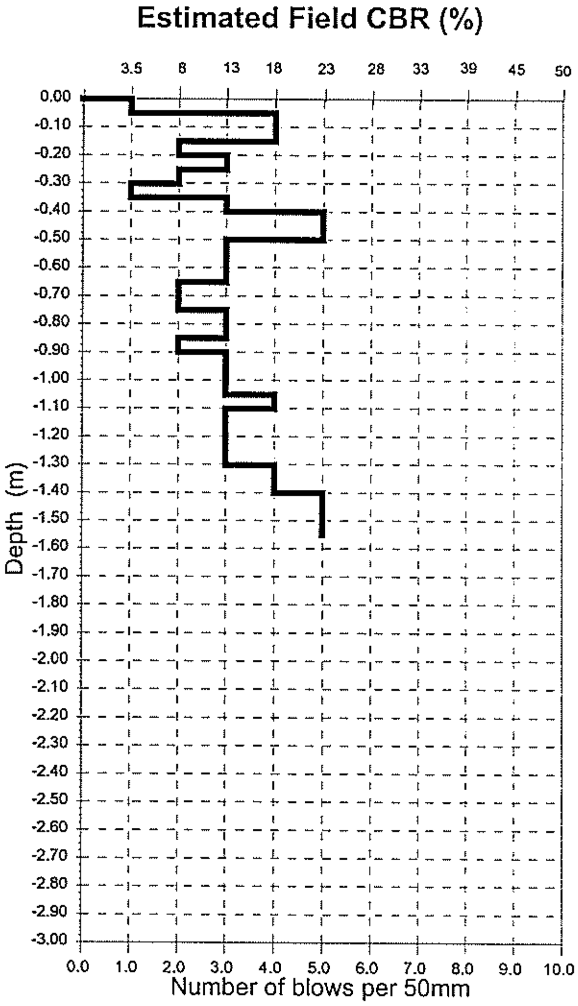
Job Name: **CBR Investigations** Job No.: **613836** Client Ref.: **Bartley RTU**
Client: **Bartley Consultants** Contractor: **Geotechnics**
Test Method Used: NZS 4402 : 1988 Test 6.5.2 Dynamic Cone Penetrometer

PAVEMENT INVESTIGATION LOG TEST REPORT

Project:	**CBR Investigations**	Sampled By:	**IW**
Location:	**Bristol Road**	Date Sampled:	**6/12/2000**
Lane:	**Left hand wheel-track**	Sampling Method:	**Test pit excavation**
Pit Location.:	**50m offset from pit No1**	Sample Condition:	**Disturbed**
Pavement Pit No.:	BR3	Date Received:	**6/12/2000**

Depth (mm)	Pavement Description
0 - 25	**Asphalt, chipseal, grade 3-4, fairly good condition**
25 - 200	**Silty GRAVEL, fine to medium, GAP40, andesite, dense to very dense, slightly moist, possibly stabilised**
200	**Top of sub-grade level**
0 - 300	**Clayey gravelly SILT, low to medium plasticity, stiff, slightly weathered - weathered GAP20, andesite gravels with a clayey silt matrix**
300 - 650	**Slightly clayey SILT, firm to stiff, low plasticity, slightly moist, light brown with orangy brown mottles**
650 - 1500	**Clayey SILT, low to medium plasticity, firm, slightly moist, light brown with orange and grey mottles**
1500	**End of auger**



Basecourse sample recovered at:	N/A	(mm)
Sub-base sample recovered at:	N/A	(mm)
Subgrade sample recovered at:	5 depths	(mm)
Depth from ground surface to: commencement of penetration:	250	(mm)

Density By Nuclear Densometer

	Basecourse	Subgrade
Wet Density (t/m3):	N/A	N/A
Dry Density (t/m3):	N/A	N/A
Water Content (%):	N/A	N/A

COMMENTS:
The estimated CBR values are based on Figure 5.2 Correlation of Dynamic Cone Penetration and CBR, AUSTROADS (1992) "Pavement Design - A guide to the Structural Design of Road Pavements"

IANZ Accreditation does not apply

Tested By: Iw Date Tested 6/12/00 Checked By: AB Date: 22/01/01

Bristol Road, Whenuapai

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Form No.:	S15b
Form Date:	Oct 1998
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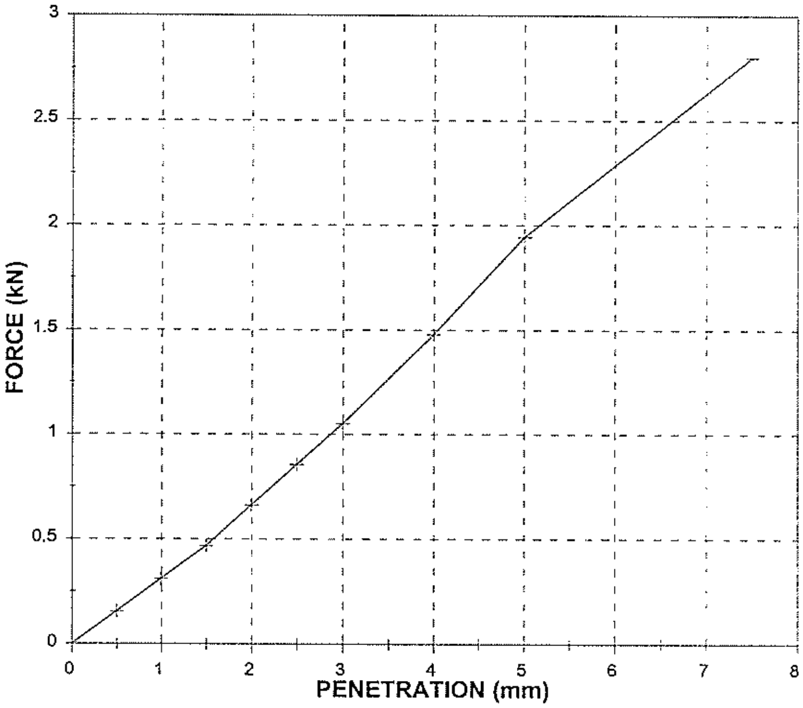
Road.: Bristol Road
Page 41 of 52
Site: Test pit BR3
Job Name: BartleyRTU
Job No.: 613836
Location: 50m from Test pit No 1
Lane.: Left hand wheel-track
Depth: -240 (mm)
Test Method Used: NZS 4402 1986 Test 6.1.3 California Bearing Ratio - In-situ method
NZS 4402 1986 Test 2.1 Determination of the Water Content

CALIFORNIA BEARING RATIO TEST- IN-SITU METHOD

Proving Ring No. : RO300
Proving Ring constant : 0.0778 (kN/div)
Water content: 60.5 (%)
Dial gauge No.: RO253

PENETRATION	FORCE	
(mm)	(div)	(kN)
0.00	0.00	0.00
0.50	2.00	0.16
1.00	4.00	0.31
1.50	6.00	0.47
2.00	8.50	0.66
2.50	11.00	0.86
3.00	13.50	1.05
4.00	19.00	1.48
5.00	25.00	1.95
7.50	36.00	2.80

CBR GRAPH



CBR RESULTS:

2.5 mm		
CORRECTED	(div)	11
FORCE	F (kN)	0.86
CBR (%)	(= F*100/13.2)	6.5
5.0 mm		
CORRECTED	(div)	25
FORCE	F (kN)	1.95
CBR (%)	(= F*100/20)	9.7
FINAL CBR VALUE:		10

Linear Regression is needed (Y/N) ? N
Initial Peneration Reading (mm): 0.00
Surcharge (Kg): 6
Base weight diameter (mm): 150
Rate of penetration by plunger (mm/min): 1/1

COMMENT:
Test performed at 240mm below top of pavement layer

MATERIAL DESCRIPTION:
As per pit log

Tested by: IW Date: 6/12/00 Checked by: AB Date: 22/01/01

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Form No.:	
Form Date:	Nov 1998
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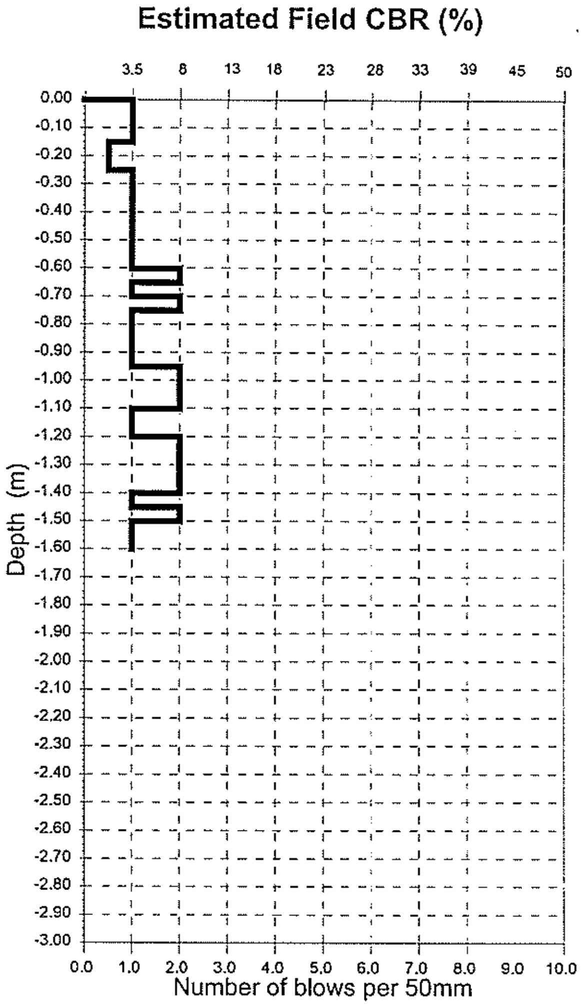
Job Name:	**CBR Investigations**	Job No.:	**613836**	Client Ref.:	**Bartley RTU**
Client:	**Bartley Consultants**	Contractor:	**Geotechnics**		
Test Method Used:	NZS 4402 : 1988 Test 6.5.2	Dynamic Cone Penetrometer			

PAVEMENT INVESTIGATION LOG TEST REPORT

Project:	**CBR Investigations**	Sampled By:	**IW**
Location:	**Bristol Road**	Date Sampled:	**6/12/2000**
Lane:	**Left hand wheel-track**	Sampling Method:	**Test pit excavation**
Pit Location.:	**50m offset from pit No2**	Sample Condition:	**Disturbed**
Pavement Pit No.:	BR5	Date Received:	**6/12/2000**

Depth (mm)	Pavement Description
0 - 25	**Asphalt, chipseal, grade 3-4, fairly good condition**
25 - 140	**Clayey plastic infill, GAP40, dense, slightly moist, greenish grey**
140 - 300	**Silty GRAVEL, GAP40, dense, slightly moist, andesite**
300	**Top of sub-grade level**
0 - 250	**SILT, soft to firm, low plasticity, slightly moist, dark brown**
250 - 1500	**Clayey SILT, slightly moist to moist, medium to high plasticity, grey with orangy brown mottles**
1500	**End of auger**



Basecourse sample recovered at:	N/A	(mm)
Sub-base sample recovered at:	N/A	(mm)
Subgrade sample recovered at:	5 depths	(mm)
Depth from ground surface to: commencement of penetration:	300	(mm)

Density By Nuclear Densometer

	Basecourse	Subgrade
Wet Density (t/m3):	N/A	N/A
Dry Density (t/m3):	N/A	N/A
Water Content (%):	N/A	N/A

COMMENTS:

The estimated CBR values are based on Figure 5.2 Correlation of Dynamic Cone Penetration and CBR, AUSTROADS (1992) "Pavement Design - A guide to the Structural Design of Road Pavements"

IANZ Accreditation does not apply

Tested By: IW Date Tested 6/12/00 Checked By: AR Date: 22/01/01

Bristol Road, Whenuapai

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TELEPHONE (09) 3556020 FAX (09) 3070265

Form No.:	S15b
Form Date:	Oct 1998
M:\iw\Bartley consult\Bristol\CBR3	

Road.: Bristol Road
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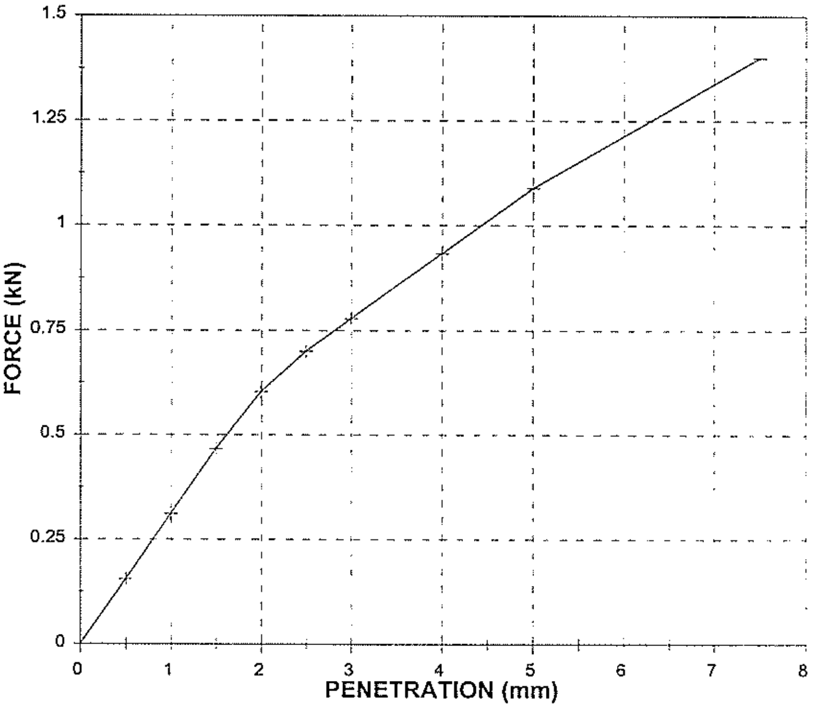
Site: Test pit BR5
Job Name: BartleyRTU
Job No.: 613836
Location: 50m from Test pit No 2
Lane.: Left hand wheel-track
Depth: -300 (mm)
Test Method Used: NZS 4402 1986 Test 6.1.3 California Bearing Ratio - In-situ method
NZS 4402 1986 Test 2.1 Determination of the Water Content

CALIFORNIA BEARING RATIO TEST- IN-SITU METHOD

Proving Ring No. : RO300
Proving Ring constant : 0.0778 (kN/div)
Water content: 60.5 (%)
Dial gauge No.: RO253

PENETRATION	FORCE	
(mm)	(div)	(kN)
0.00	0.00	0.00
0.50	2.00	0.16
1.00	4.00	0.31
1.50	6.00	0.47
2.00	7.75	0.60
2.50	9.00	0.70
3.00	10.00	0.78
4.00	12.00	0.93
5.00	14.00	1.09
7.50	18.00	1.40

CBR GRAPH



CBR RESULTS:

2.5 mm		
CORRECTED	(div)	9
FORCE	F (kN)	0.70
CBR (%)	(= F*100/13.2)	5.3
5.0 mm		
CORRECTED	(div)	14
FORCE	F (kN)	1.09
CBR (%)	(= F*100/20)	5.4
FINAL CBR VALUE:		5

Linear Regression is needed (Y/N) ? N
Initial Peneration Reading (mm): 0.00
Surcharge (Kg): 6
Base weight diameter (mm): 150
Rate of penetration by plunger (mm/min): 1/1

COMMENT:
Test performed at 300mm below top of pavement layer

MATERIAL DESCRIPTION:
As per pit log

Tested by: IW
Date: 6/12/00
Checked by: AB
Date: 22/01/01

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Form No.:	
Form Date:	Nov 1998
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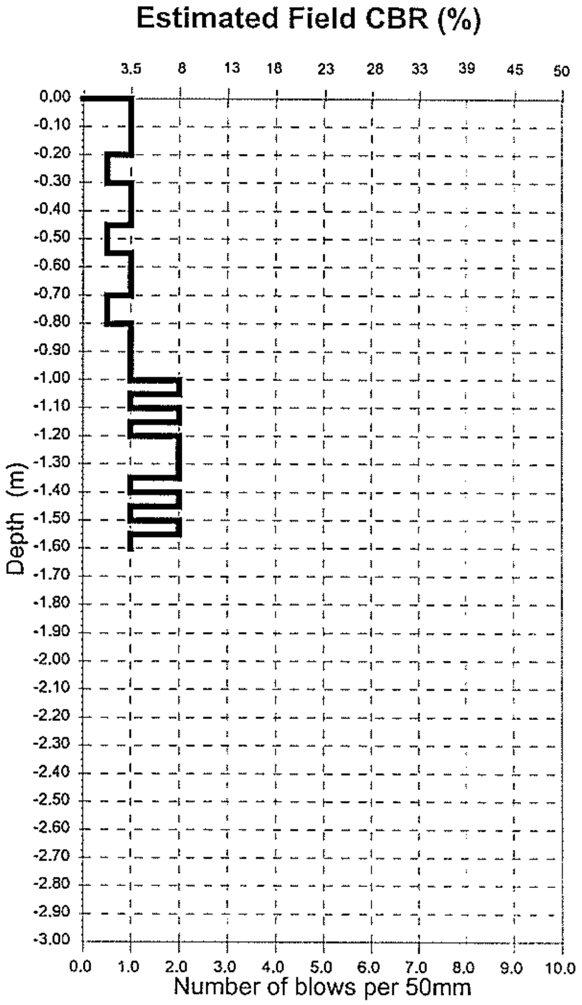
Job Name:	**CBR Investigations**	Job No.:	**613836**	Client Ref.:	**Bartley RTU**
Client:	**Bartley Consultants**	Contractor:	**Geotechnics**		
Test Method Used:	NZS 4402 : 1988 Test 6.5.2	Dynamic Cone Penetrometer			

PAVEMENT INVESTIGATION LOG TEST REPORT

Project:	**CBR Investigations**	Sampled By:	**IW**
Location:	**Bristol Road**	Date Sampled:	**15/12/2000**
Lane:	**Centre of the road**	Sampling Method:	**Test pit excavation**
Pit Location.:	**Adjacent to pit No3**	Sample Condition:	**Disturbed**
Pavement Pit No.:	BR6	Date Received:	**15/12/2000**

Depth (mm)	Pavement Description
0 - 25	**Asphalt, chipseal, grade 3-4, fairly good condition**
25 - 140	**Clayey plastic infill, GAP40, dense, slightly moist, greenish grey**
140 - 370	**Silty GRAVEL, GAP40, dense, slightly moist, andesite**
370	**Top of sub-grade level**
0 - 200	**SILT, soft to firm, low plasticity, slightly moist, dark brown**
200 - 1500	**Clayey SILT, slightly moist to moist, medium to high plasticity, grey with orangy brown mottles**
1500	**End of auger**



Basecourse sample recovered at:	N/A	(mm)
Sub-base sample recovered at:	N/A	(mm)
Subgrade sample recovered at:	5 depths	(mm)
Depth from ground surface to:	400	(mm)
commencement of penetration:		

Density By Nuclear Densometer

	Basecourse	Subgrade
Wet Density (t/m3):	N/A	N/A
Dry Density (t/m3):	N/A	N/A
Water Content (%):	N/A	N/A

COMMENTS:

The estimated CBR values are based on Figure 5.2 Correlation of Dynamic Cone Penetration and CBR, AUSTROADS (1992) "Pavement Design - A guide to the Structural Design of Road Pavements"

IANZ Accreditation does not apply

Tested By: Iw   Date Tested 15/12/00   Checked By: AR   Date: 22/01/01

Bristol Road, Whenuapai

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Form Date:	Oct 1998
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Road.: Bristol Road

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Site: Test pit BR6 Job Name: BartleyRTU Job No.: 613836

Location: Adjacent to pit No 3 Lane.: Centre of road Depth: -400 (mm)

Test Method Used: NZS 4402 1986 Test 6.1.3 California Bearing Ratio - In-situ method
NZS 4402 1986 Test 2.1 Determination of the Water Content

CALIFORNIA BEARING RATIO TEST- IN-SITU METHOD

Proving Ring No. : RO300

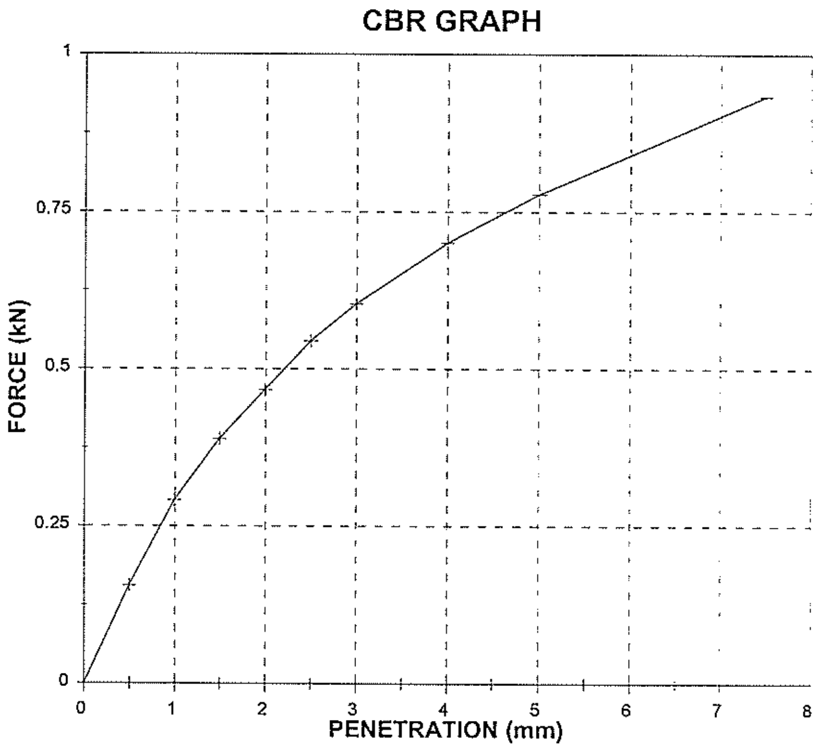
Proving Ring constant : 0.0778 (kN/div)

Water content: 50.4 (%)

Dial gauge No.: RO253

PENETRATION	FORCE	
(mm)	(div)	(kN)
0.00	0.00	0.00
0.50	2.00	0.16
1.00	3.75	0.29
1.50	5.00	0.39
2.00	6.00	0.47
2.50	7.00	0.54
3.00	7.75	0.60
4.00	9.00	0.70
5.00	10.00	0.78
7.50	12.00	0.93

CBR GRAPH



CBR RESULTS:

2.5 mm		
CORRECTED FORCE	(div)	7
	F (kN)	0.54
CBR (%)	(= F*100/13.2)	4.1
5.0 mm		
CORRECTED FORCE	(div)	10
	F (kN)	0.78
CBR (%)	(= F*100/20)	3.9
FINAL CBR VALUE:		4

Linear Regression is needed (Y/N) ? N

Initial Peneration Reading (mm): 0.00

Surcharge (Kg): 6

Base weight diameter (mm): 150

Rate of penetration by plunger (mm/min): 1/1

COMMENT:

Test performed at 400mm below top of pavement layer

MATERIAL DESCRIPTION:

As per pit log

Tested by: IW Date: 15/12/00 Checked by: AB Date: 22/01/01

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Form No.:	
Form Date:	Nov 1998
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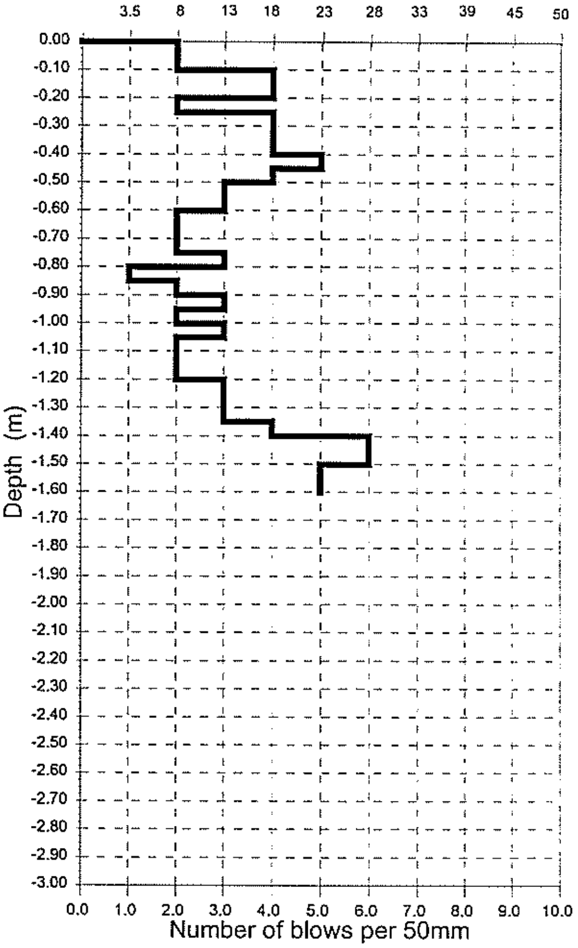
Job Name: **CBR Investigations** Job No.: **613836** Client Ref.: **Bartley RTU**
Client: **Bartley Consultants** Contractor: **Geotechnics**
Test Method Used: NZS 4402 : 1988 Test 6.5.2 Dynamic Cone Penetrometer

PAVEMENT INVESTIGATION LOG TEST REPORT

Project:	**CBR Investigations**	Sampled By:	**IW**
Location:	**Bristol Road**	Date Sampled:	**15/12/2000**
Lane:	**Centre of the road**	Sampling Method:	**Test pit excavation**
Pit Location.:	**Adjacent to pit No2**	Sample Condition:	**Disturbed**
Pavement Pit No.:	BR4	Date Received:	**15/12/2000**

Depth (mm)	Pavement Description
0 - 25	**Asphalt, chipseal, grade 3-4, fairly good condition**
25 - 200	**Clayey plastic infill, GAP40, dense, slightly moist, greenish grey**
200 - 300	**Silty GRAVEL, GAP40, dense, slightly moist, andesite**
300	**Top of sub-grade level**
0 - 150	**SILT, sands to fine, firm, slightly moist, dark brown**
150 - 400	**Slightly clayey SILT, firm to stiff, slightly moist medium plasticity, light brown**
400 - 1500	**Clayey SILT, stiff, medium to high plasticity, slightly moist, orangy brown**
1500	**End of auger**

Estimated Field CBR (%)



Basecourse sample recovered at:	N/A	(mm)
Sub-base sample recovered at:	N/A	(mm)
Subgrade sample recovered at:	5 depths	(mm)
Depth from ground surface to:	300	(mm)
commencement of penetration:		

Density By Nuclear Densometer

	Basecourse	Subgrade
Wet Density (t/m3):	N/A	N/A
Dry Density (t/m3):	N/A	N/A
Water Content (%):	N/A	N/A

COMMENTS:
The estimated CBR values are based on Figure 5.2 Correlation of Dynamic Cone Penetration and CBR, AUSTROADS (1992) "Pavement Design - A guide to the Structural Design of Road Pavements"

IANZ Accreditation does not apply

Tested By: IW Date Tested 15/12/00 Checked By: AB Date: 22/01/01

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Form No.:	S15b
Form Date:	Oct 1998
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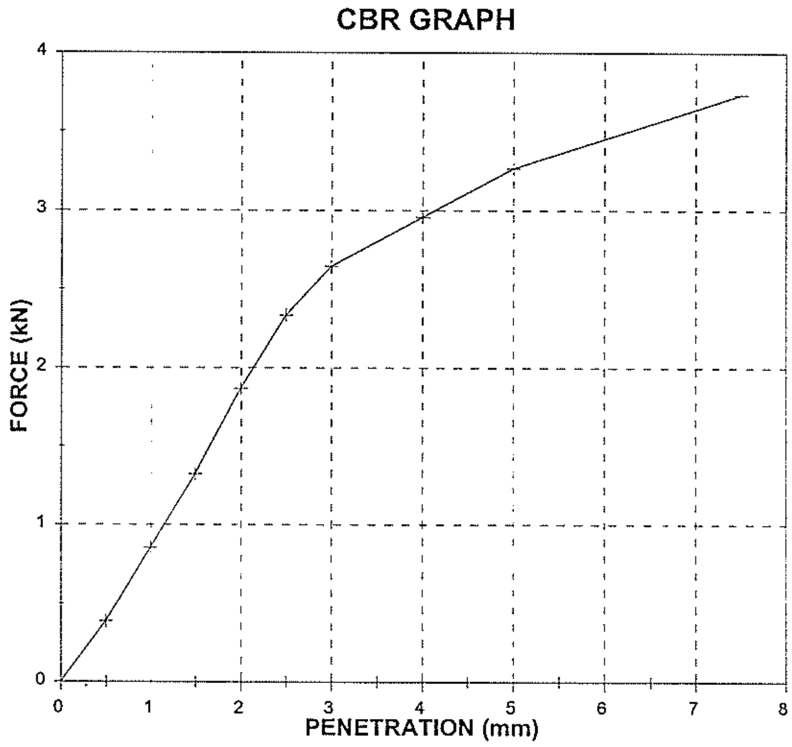
Road.: Bristol Road
Page 4 of 52
Site: Test pit BR4
Job Name: BartleyRTU
Job No.: 613836
Location: Adjacent to pit No 2
Lane.: Centre of road
Depth: -300 (mm)
Test Method Used: NZS 4402 1986 Test 6.1.3 California Bearing Ratio - In-situ method
NZS 4402 1986 Test 2.1 Determination of the Water Content

CALIFORNIA BEARING RATIO TEST- IN-SITU METHOD

Proving Ring No. : RO300
Proving Ring constant : 0.0778 (kN/div)
Water content: 81.2 (%)
Dial gauge No.: RO253

PENETRATION	FORCE	
(mm)	(div)	(kN)
0.00	0.00	0.00
0.50	5.00	0.39
1.00	11.00	0.86
1.50	17.00	1.32
2.00	24.00	1.87
2.50	30.00	2.33
3.00	34.00	2.65
4.00	38.00	2.96
5.00	42.00	3.27
7.50	48.00	3.73



CBR RESULTS:

2.5 mm		
CORRECTED FORCE	(div)	30
	F (kN)	2.33
CBR (%)	(= F*100/13.2)	17.7
5.0 mm		
CORRECTED FORCE	(div)	42
	F (kN)	3.27
CBR (%)	(= F*100/20)	16.3
FINAL CBR VALUE:		18

Linear Regression is needed (Y/N) ?	N
Initial Peneration Reading (mm):	0.00
Surcharge (Kg):	6
Base weight diameter (mm):	150
Rate of penetration by plunger (mm/min):	1/1

COMMENT:
Test performed at 300mm below top of pavement layer

MATERIAL DESCRIPTION:
As per pit log

Tested by: IW Date: 15/12/00 Checked by: AB Date: 22/01/01

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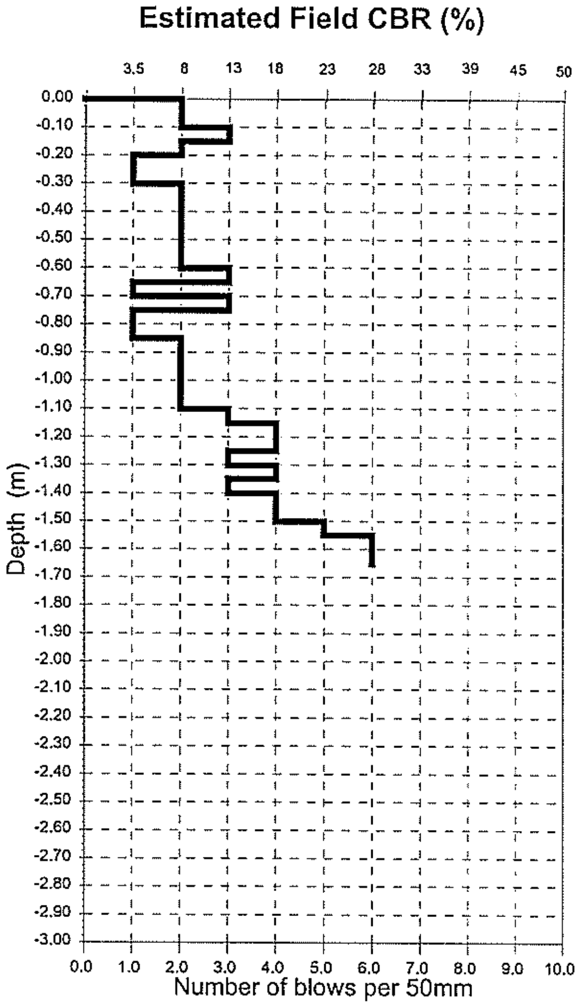
Job Name: **CBR Investigations** Job No.: **613836** Client Ref.: **Bartley RTU**
Client: **Bartley Consultants** Contractor: **Geotechnics**
Test Method Used: NZS 4402 : 1988 Test 6.5.2 Dynamic Cone Penetrometer

PAVEMENT INVESTIGATION LOG TEST REPORT

Project: **CBR Investigations**
Location: **Bristol Road**
Lane: **Centre of the road**
Pit Location.: **Adjacent to pit No1**
Pavement Pit No.: BR2

Sampled By: **IW**
Date Sampled: **15/12/2000**
Sampling Method: **Test pit excavation**
Sample Condition: **Disturbed**
Date Received: **15/12/2000**

Depth (mm)	Pavement Description
0 - 25	**Asphalt, chipseal, grade 3-4, fairly good condition**
25 - 150	**Silty clayey plastic infill, GAP40, dense, slightly moist, greenish grey**
150 - 250	**Very silty GRAVEL, medium dense, aggregate pushed into silty sub-grade**
250	**Top of sub-grade level**
0 - 200	**SILT, firm to stiff, dry to slightly moist, low plasticity, light brown**
200 - 450	**Slightly clayey SILT, firm to stiff, slightly moist medium plasticity, orangy brown**
450 - 1500	**Clayey SILT, stiff to very stiff, medium to high plasticity, slightly moist, light grey**
1500	**End of auger**


Estimated Field CBR (%)

Basecourse sample recovered at:	N/A	(mm)
Sub-base sample recovered at:	N/A	(mm)
Subgrade sample recovered at:	5 depths	(mm)
Depth from ground surface to: commencement of penetration:	250	(mm)

Density By Nuclear Densometer

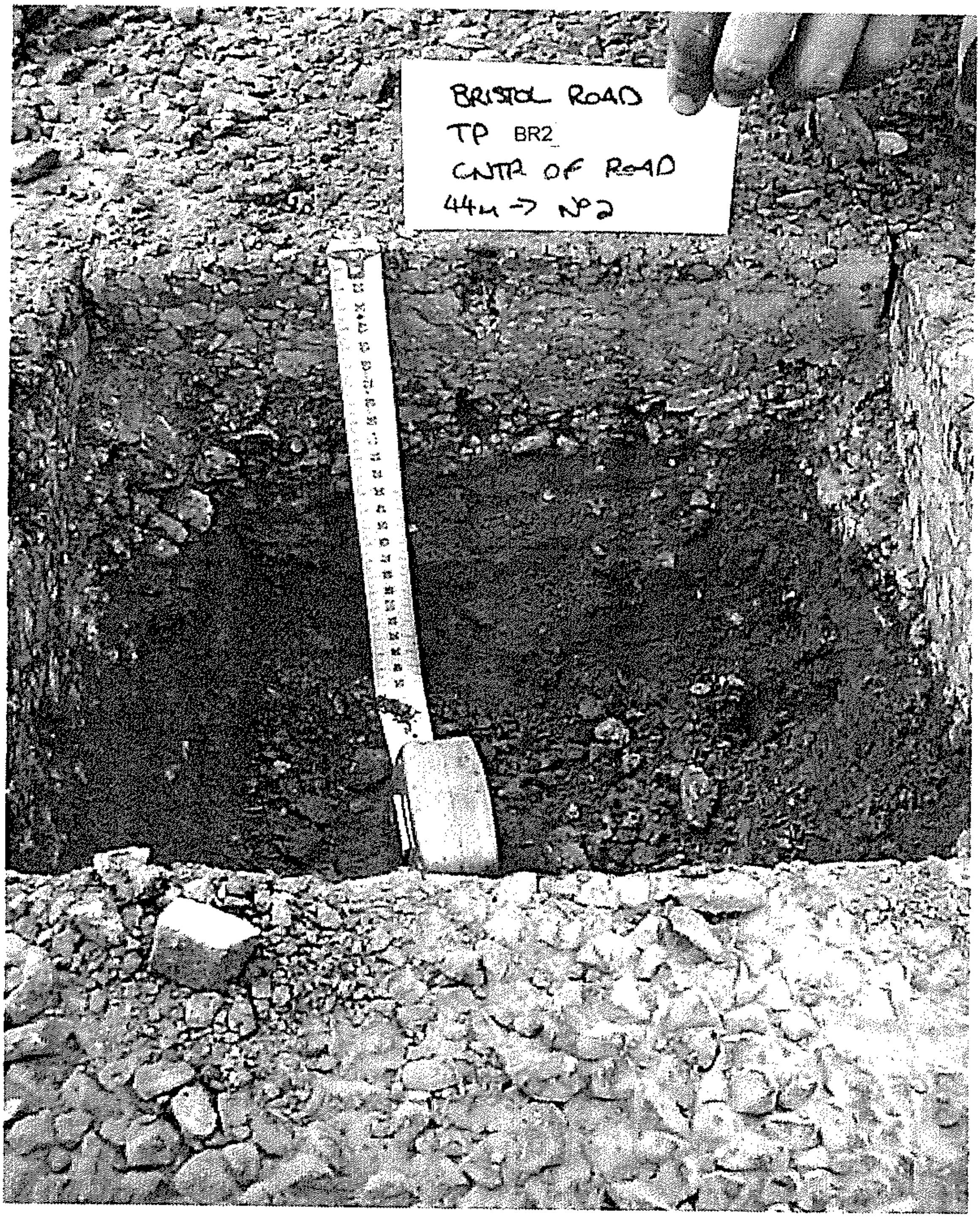
	Basecourse	Subgrade
Wet Density (t/m3):	N/A	N/A
Dry Density (t/m3):	N/A	N/A
Water Content (%):	N/A	N/A

COMMENTS:
The estimated CBR values are based on Figure 5.2 Correlation of Dynamic Cone Penetration and CBR, AUSTROADS (1992) "Pavement Design - A guide to the Structural Design of Road Pavements"

IANZ Accreditation does not apply

Tested By: IW Date Tested 15/12/00 Checked By: AB Date: 22/01/01

Bristol Road, Whenuapai



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Form No.:	S15b
Form Date:	Oct 1998
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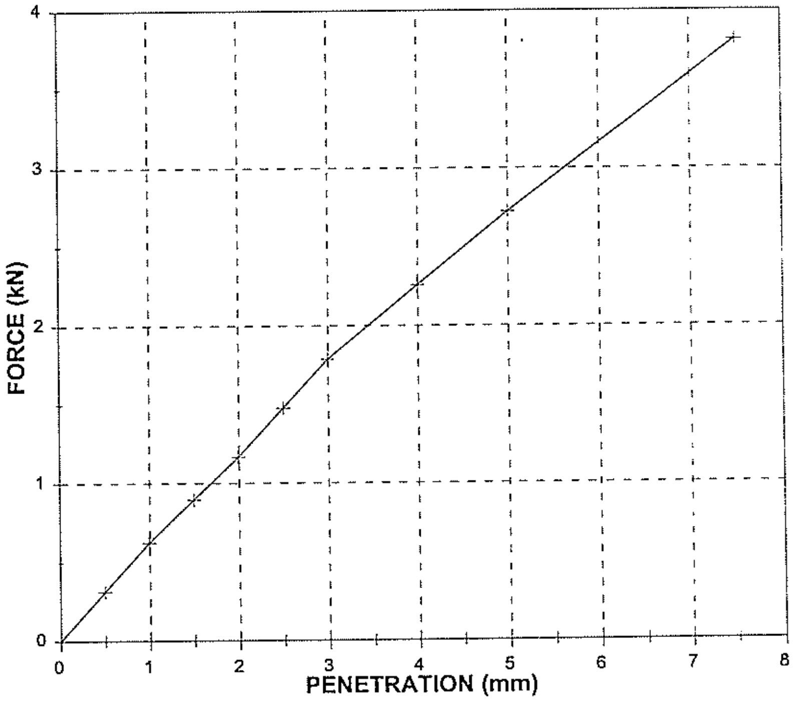
Road.: Bristol Road
Site: Test pit BR2
Job Name: BartleyRTU
Job No.: 613836
Location: Adjacent to pit No 1
Lane.: Centre of road
Depth: -250 (mm)
Test Method Used: NZS 4402 1986 Test 6.1.3 California Bearing Ratio - In-situ method
NZS 4402 1986 Test 2.1 Determination of the Water Content

CALIFORNIA BEARING RATIO TEST- IN-SITU METHOD

Proving Ring No. : RO300
Proving Ring constant : 0.0778 (kN/div)
Water content: 74.7 (%)
Dial gauge No.: RO253

PENETRATION (mm)	FORCE (div)	FORCE (kN)
0.00	0.00	0.00
0.50	4.00	0.31
1.00	8.00	0.62
1.50	11.50	0.89
2.00	15.00	1.17
2.50	19.00	1.48
3.00	23.00	1.79
4.00	29.00	2.26
5.00	35.00	2.72
7.50	49.00	3.81

CBR GRAPH



CBR RESULTS:

2.5 mm		
CORRECTED FORCE	(div)	19
	F (kN)	1.48
CBR (%)	(= F*100/13.2)	11.2
5.0 mm		
CORRECTED FORCE	(div)	35
	F (kN)	2.72
CBR (%)	(= F*100/20)	13.6
FINAL CBR VALUE:		14

Linear Regression is needed (Y/N) ? N
Initial Peneration Reading (mm): 0.00
Surcharge (Kg): 6
Base weight diameter (mm): 150
Rate of penetration by plunger (mm/min): 1/1

COMMENT:
Test performed at 250mm below top of pavement layer

MATERIAL DESCRIPTION:
As per pit log

ted by: IW Date: Checked by: Date: