University of Southern Queensland

Faculty of Health, Engineering and Sciences

Development of a sustainable footpath material using recycled road profile, natural soils and PolyCom Stabilising Aid

A dissertation submitted by

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ABSTRACT

Recycling and sustainability is a key element that needs to be addressed in modern day construction, to ensure the preservation of resources for future generations. The Ipswich City Council currently removes road profile and stores it for future use; and have only recently begun considering, researching and testing possible uses for it. This project aims to investigate the feasibility of using a material that is 99.998% -100% recycled, and is also suitable for use for pedestrian thoroughfare. Current research pertaining to road profile use has indicated that it requires improvement, thus the natural soils found within the Ipswich region and PolyCom Stabilising Aid will be utilised in an attempt to provide the stabilisation that the road profile might require. Laboratory testing of four different soils and road profile with and without PolyCom will occur. Different mix proportions of the four common soils of the Ipswich region and road profile will be tested, and the optimal mix proportion will be tested with and without the addition of the PolyCom Stabilising agent in California Bearing Ratio (CBR), Unconfined Compressive Strength (UCS) and Slip Resistance tests.

The successful application of this project will provide many benefits to Councils and thoroughfare construction industries by providing a more sustainable material that is cheaper than traditional reinforced concrete. Furthermore, this material may be an alternative for concrete in rural areas, and may also act well to provide thoroughfare in emergency situations, as it does not require curing like other materials.

Testing has indicated that the Road Profile does indeed benefit from the addition of soil, especially in samples that feature mix proportions of 25% Road Profile to 75% soil, and even 50% Road Profile to 50% soil. These samples demonstrate improved stabilisation when compared to samples of 100% Road Profile, and improved strength when compared to 100% soil samples. Optimal mixtures of road profile and soil samples reached CBR ratings of 70% - 80%.

When added with PolyCom Stabilising Aid, the Road Profile and soil mixtures did not perform very well in soaked CBR tests, revealing that in wet conditions, the PolyCom Stabiliser does not work well with the given materials. However, when tested in dry conditions in the Unconfined Compressive Strength tests, strengths of 1.82 MPa to 2.37 MPa were achieved by the Road Profile, Soil and PolyCom mixtures.

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Limitations of Use

Certification

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Mr. Scott Ervin Jackson

Student Number: 0061043993

Signature

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Date

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CHAPTER 1 - INTRODUCTION

1.1 Project Background

Modern day pavement utilises many different materials during the construction process. As the demand for more infrastructure and road development increases with population growth, there becomes greater need for more sustainable methods and materials for pavement construction. The current era brings an increasing number of businesses, schools, transportation and residential areas that are being developed within walking distance of each other, creating larger volumes of pedestrian traffic. To ensure the safety of all traffic users (whether pedestrian or vehicular), there is an increasing requirement for Councils to provide footpaths for the safe passage of pedestrian traffic, and to ensure that the two types of traffic are kept separate from each other to minimise accidents. Pavement materials, such as footpaths, should address the need for sustainability by being made from recycled materials, being environmentally friendly and by being financially practical.

There is currently an increasing amount of road profile that is being stored or dumped into landfill as it has no use, which is another issue that has arisen over the years. Road profile is essentially a part of the road (ranging from materials that include the base, subbase and surface layers) that has been removed due to degradation or changing requirements. Once a road has served its purpose or is no longer appropriate for use, the road is removed and the subsequent materials are deposited elsewhere as there is no use for them. This is becoming an ever increasing issue in modern construction as the current methods are both expensive and unsustainable, and the result is excess amounts of unusable road profile.

Many City Councils are facing similar situations in which multiple problems are arising in their pavement development. These issues have prompted councils and researchers to consider new techniques in an attempt to reduce costs and increase sustainability; however, there is still little research available. Research on the utilisation of recycled and waste materials within cement and concrete is increasing vastly; however, it is necessary to take a further step and research new possibilities of recycling that do not utilise concrete and/or cement.

1.2 Research Aims

This project aims to address the following two issues:

- Developing a sustainable footpath material
- Providing a use for road profile

These two issues can be addressed by one solution; utilising the reclaimed road profile for the construction and maintenance of footpaths. Recycling road profile will ensure that the road materials are put to as much as use as possible and may potentially provide a more cost efficient and sustainable solution for the creation of footpaths, with minimum environmental impact. The Ipswich City Council currently removes road profile and stores it for future use that is unknown, and due to such, a large supply of the road profile material is available for use. Ipswich City Council's current research and testing of the road profile material has found it to require improvement and stabilisation, and the road profile material currently performs better when mixed with another material (such as gravel). The Council has only been conducting research using road profile for the purposes of creating an unsealed road material, and very little to no research is currently available regarding recycling road profile.

This project aims to create a new material that can be utilised for footpaths and pedestrian thoroughfare, using recycled road profile, soil and a stabilising agent (PolyCom). There is currently no research available on the usage of soil and road profile, and very little research on the usage of road profile. Most research available for road profile like materials focuses on utilising the material for road purposes, rather than for pedestrian thoroughfare.

Therefore, this project aims to address the knowledge gap on the use of recycled materials for footpaths and will also address the knowledge gap of utilising soil to stabilise road profile.

The major objectives for this research are to:

- Develop a material for footpaths utilising recycled road profile, naturally occurring soils around Ipswich and PolyCom Stabilising Aid.
- Conduct research regarding footpath materials, pavement standards, soils within the region, erosion and recycled road profile characteristics.
- Propose a footpath design and identify the parameters for testing.
- Perform relevant standard tests such as California Bearing Ratio Test, Standard Compaction Test, Compressive Strength Test and Slip Resistance.

- Analyse results and characteristics relating to strength, slip resistance and compaction rates.
- Compare and evaluate the results of recycled road profile / natural soil mixtures with and without PolyCom.
- Compare and evaluate results between PolyCom mixtures and N-20 concrete samples.
- Identify optimal mixtures of recycled road profile for different soils from laboratory testing.

Refer to the project specifications provided in Appendix A for a complete description of the research objectives for this project. Chapter 2 provides a review of available literature, on recycled road profile materials and their properties.

CHAPTER 2 – LITERATURE REVIEW

2.1 Material Properties

The following sections will explore some of the properties that may be tested to evaluate the samples of recycled road profile, soil and PolyCom mixtures. These include evaluating the maximum dry density and optimal moisture content, California bearing ratio, unconfined compressive strength, slip resistance and erosion characteristics.

2.1.1 Proctor Compaction Test

The Proctor Compaction Test is a laboratory test that identifies the compaction properties of a soil. It determines the optimal moisture content (%) required for a soil to reach maximum dry density (Mg/m^3) (Proctor Compaction Test, 2013). There are two main types of compaction methods used in the civil engineering discipline, which are the Standard Proctor Compaction test (as described by AS 1289.5.1.1-2003), and the Modified Proctor Compaction test (as defined by AS 1289.5.2.1-2003). The following equations are used to derive the wet density (ρ) and dry density (ρ_d) of the soils, using AS 1289.5.2.1-2003 (Australian Standard, 2003).

$$\rho = \frac{m_2 - m_1}{V} \qquad \text{Equation 2.1}$$

Where:

m_1 = mass of the mould and baseplate (g)

m_2 = mass of the mould, baseplate and specimen (g)

V = volume of the mould (cm^3)

ρ = density of wet soil (Mg/m^3)

$$\rho_d = \frac{\rho \times 100}{100 + w} \qquad \text{Equation 2.2}$$

Where:

ρ = density of wet soil (Mg/m^3)

w = moisture content (%)

ρ_d = dry density of soil (Mg/m^3)

The difference between the two tests lies in the compaction effort of the tests, as the Standard test utilises a 2.7 kg rammer from a drop of 300 mm (Australian Standard, 2003), whereas the Modified test utilises a 4.9 kg rammer from a drop of 450 mm (Australian Standard, 2003). An illustration of the differences is provided in Figure 2.1 below. Due to this difference, the Standard test delivers 7.94 Joules of energy per blow, while the Modified test delivers 21.62 Joules of energy per blow, producing a much greater compaction effort (Australian Standard, 2003). The Standard test also only utilises 3 layers of soil, while the Modified test requires 5 layers to be compacted into the mould (when utilising a size 19 sieve) (Australian Standard, 2003). The dimensions (diameter, arc, radius and area) of the rammer are the same in both tests, and the number of blows per layer in each test is also the same, at 25 blows per layer (Australian Standard, 2003). The procedures of the Modified Proctor Compaction test will be discussed in later chapters.

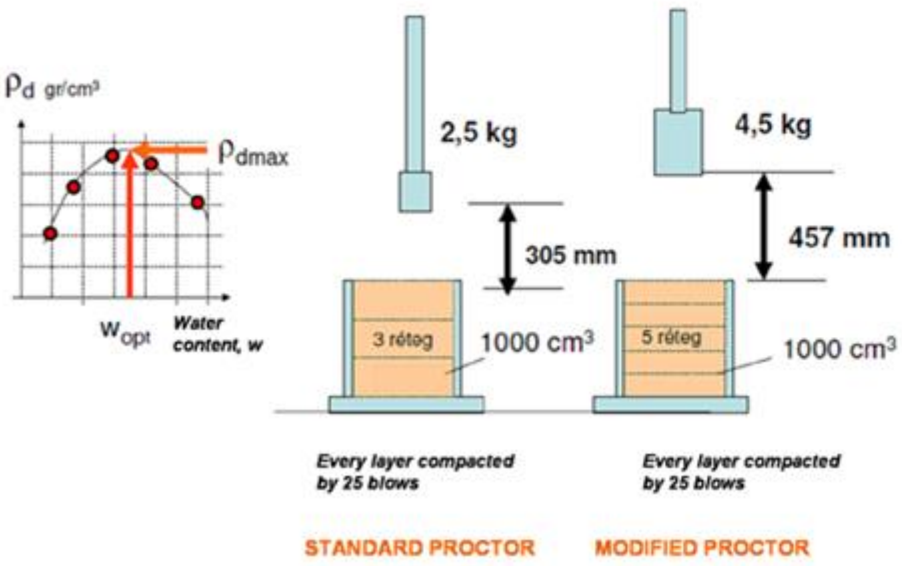

Figure 2.1: Diagram of Standard Proctor and Modified Proctor Test (Beata & Imre, 2011)

The Standard and Modified Proctor Compaction tests yield close to the same results, however, the Modified Proctor tests yields slightly better results. This was indicated in the research conducted by Arulrajah et al. (2011), which revolved around the use of crushed grass in road work applications. The studies utilised both the Standard and Modified Proctor tests, which indicated the Modified Proctor Compaction test required the samples to features a lower optimal water content, while simultaneously achieving a higher maximum dry density. The Standard Proctor test resulted in a maximum dry density of 1.70 Mg/m^3 for fine crushed glass and 1.83 Mg/m^3 for medium crushed glass, while requiring 12.5% and 9% moisture contents, respectively (Arulrajah et al., 2011). The Modified Proctor Compaction tests yielded a maximum dry density of 1.78 Mg/m^3 for fine crushed glass, and 1.99 Mg/m^3 for medium crushed glass, requiring only 10% and 8.8% moisture contents, respectively (Arulrajah et al., 2011). For testing purposes, it is important to keep this difference in mind, as the Modified Proctor Compaction tests will yield greater results.

After identifying the differences in the compaction testing, it is important to understand how this may also relate to the use of recycled road profile. There is limited information available on the compaction results of recycled road profile itself; therefore, it is necessary to consider other recycled materials that may be similar. Arulrajah et al. (2014) discusses the use of Recycled Asphalt Pavement (RAP) as a base or subbase material. The research of the authors indicates that RAP (consisting of 48% gravel, 46% sand and 6% fines with particle size of 20 mm or less) requires an optimal moisture content of 8.1%, to provide a maximum dry density of 20 kN/m^3, when compacted according to the Modified Proctor Compaction, as shown in Figure 2.2 below. This is approximately 2 Mg/m^3 (2 tonnes per cubic metre), and is found at the peak of the curve. Figure 2.2 also indicates the dry density to moisture content relationship for 5 other recycled materials including crushed brick, recycled concrete aggregate, waste excavation rock, and medium and fine recycled glass.

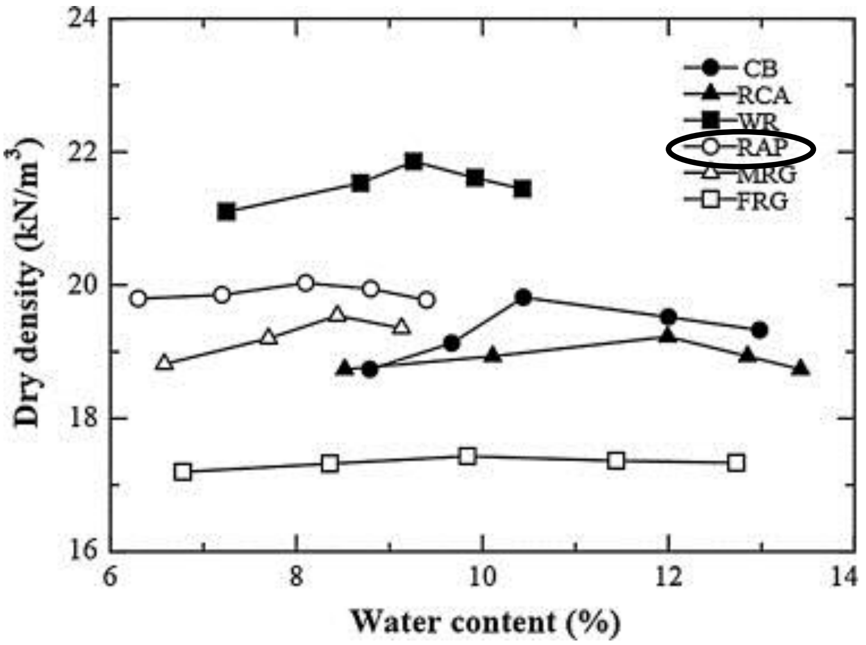

Figure 2.2: Dry density–water content relationships for Construction & Demolition materials (Arulrajah 2014)

Another study conducted by Arulrajah et al. (2014) also confirmed that the RAP provided a dry density ranging between 1.7 g/cm^3 and 2.1 g/cm^3 (equivalent to 1.7 Mg/m^3 and 2.1 Mg/m^3). To provide a scale to measure against, most normal class concretes feature a mass per unit volume of approximately 2.4 Mg/m^3 (Holcim, 2016), as per the default design value in AS3600, and can generally range between 2.1 Mg/m^3 to 2.8 Mg/m^3 (Pietrosanto, 2015). The maximum dry density of Recycled Asphalt Pavement is slightly lower than concrete, which is important to keep in mind when comparing results.

2.1.2 California Bearing Ratio

The California Bearing Ratio (CBR) test is a penetration test that evaluates the mechanical strength of road sub grades and base courses, and was developed by the California Department of Transportation in the 1930's (Galbriath, 2015). The CBR test is now utilised more for categorisation purposes rather than design purposes, as it provides an index of strength. CBR Testing is commonly utilised for the testing of many different pavements including pathways, roads and airstrips, and is also used to assess soils where pavements are already present (Galbriath, 2015).

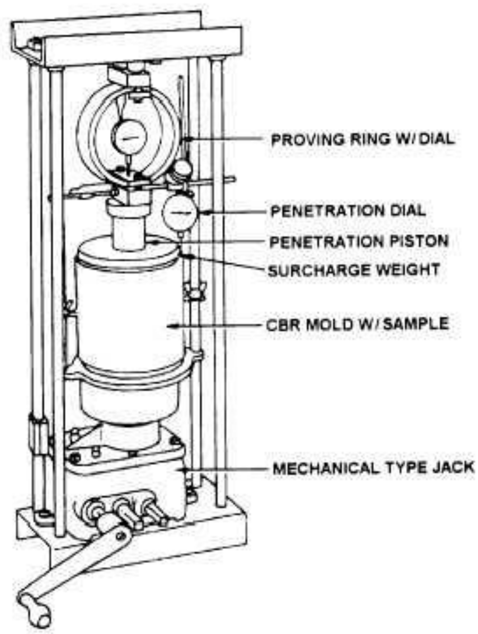

Figure 2.3: CBR Testing Machine (Integrated Publishing Inc., 2016)

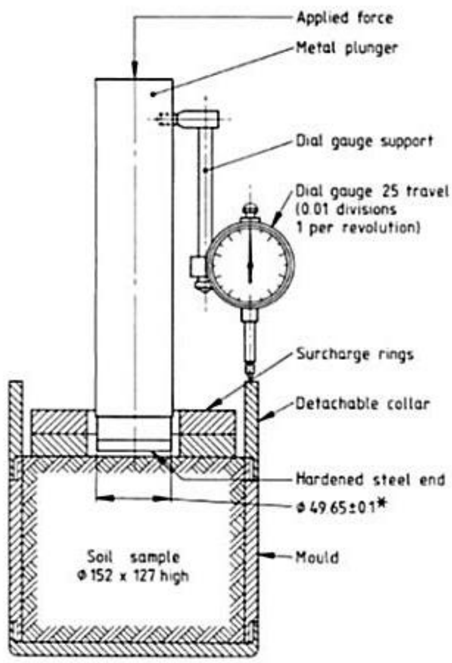

Figure 2.4: CBR Testing Setup – closer look (G Techcon, 2014)

Figure 2.3 illustrates a typical CBR testing machine, while Figure 2.4 depicts the smaller details of the sample positioning, gauges and piston. The CBR of a sample is calculated from data recorded from the dial gauge during the penetration test. Penetration is applied at a constant rate of 1.0 ± 0.2 mm/min, and it is necessary to take load readings at the penetrations of 0.5 mm for the first 6 readings (i.e. 0.5, 1.0, 1.5, 2.0, 2.5, 3.0) and then at penetrations of 4 mm, 5 mm, 7.5 mm, 10 mm and 12.5 mm (Australian Standard, 2014). It is important to note that where the strength of the specimen is such that a penetration of at least 2.5 mm cannot be achieved, it is necessary to stop the test and record the load and the actual maximum penetration achieved (Australian Standard, 2014). CBR values should be recorded to the nearest values, as given in Table 2.1.

Table 2. 1: CBR Value reporting requirements (Standards Australia, 2014)

CBR (%)	Report value to the nearest
≤5	0.5
>5 to ≤20	1
>20 to ≤50	5
>50	10

After conducting the CBR test, a range of data will be available to plot the load penetration curve with. After plotting the load penetration curve, the CBR can be calculated by taking the force value in kilonewtons (kN) at the penetrations of 2.5 mm and 5 mm and dividing by 13.2 kN and 19.8 kN respectively, and multiplying by 100. Conducting the CBR tests can yield other types of information including the dry density, laboratory density and moisture ratios, variation between moisture contents, swell and volume and moisture contents of a soaked sample (Australian Standard, 2014), through different calculations.

Table 2. 2: CBR Properties of recycled materials (Arulrajah et al., 2014)

Engineering properties	RCA	CB	WR	RAP	FRG	MRG	Typical quarry materials
CBR (%)	118 - 160	123 - 138	121 - 204	30 - 35	42 - 46	73 - 76	>80

The results shown in Table 2.2 are from research conducted by Arulrajah et al. (2014). Their research indicates that Recycled Asphalt Pavement (RAP) provided a CBR of only 30% to 35%. Arulrajah et al. (2014) indicates that the lower CBR performance is due to reduced water absorption (i.e. RAP has poor water absorption as the particles may still have sealing materials on them). Through Arulrajah's research, the conclusion can be drawn that the likely CBR rating of a recycled material may be influenced by the size of the particles and the water absorption qualities of the recycled material, which impact compaction and maximum dry density and ultimately affect the CBR. Another study conducted by Arulrajah et al. (2014) found their recycled asphalt pavement mixture to provide a CBR of 39%. The results from both studies are quite similar, drawing the conclusion that Recycled Asphalt Pavement (and therefore, road profile) generally provides a CBR of 30% – 40%.

2.1.3 Compressive Strength

The compressive strength of material relates to the maximum compressive stress that a material can sustain before fracture, under a gradually applied load (Merriam-Webster, 2015). Compression testing is often performed on brittle materials such as concrete (MEC1201 Engineering Materials, 2013) to identify their strength properties. Compression testing generally utilises a distinct approach, by placing the specimen between two pads. The specimen is squeezed between the adjustable cross-head and bed plates until failure occurs (as shown in Figure 2.5) (MEC1201 Engineering Materials, 2013). Compressive strength tests are undertaken according to Australian Standard AS 1012.9: 2014 (Standards Australia 2014) for concrete and AS 5101.4-2008 (Standards Australia 2008) for compacted materials. It is important to note that there are two methods of compressive strength testing, confined and unconfined; however, for the purposes of this report, only unconfined compressive strength testing will be performed and as such all references to compressive strength testing are in relation to the unconfined method.

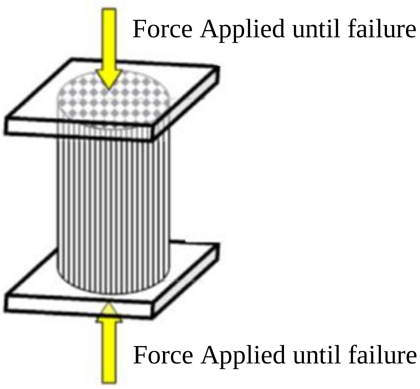

Figure 2.5: Compressive strength diagram (MEC1201 Engineering

For the purposes of this project, the material produced will be measured in comparison with N25 concrete, as this is the closest strength grade available for purchase (Ipswich City Council currently uses N20). For this reason, it is necessary to identify the equations and procedures utilised to determine the strength of concrete. Compressive strength testing for concrete is calculated by the maximum load divided by the original cross-sectional area (MEC1201 Engineering Materials, 2013). Compressive strength testing allows for stress and strain to be calculated. Stress (σ) is defined as the force (F) over the cross section area (A) (MEC1201 Engineering Materials 2013), given by the following equation.

$$\sigma = \frac{F}{A}$$ Equation 2.3

When a material is subjected to a load (generating stress), the material reacts through a change in shape, which is known as deformation. Strain (ε) is calculated as the deformation divided by the original dimension (L) (Glossop 2013), defined as the following equation.

Equation 2.4

$$\varepsilon = \frac{L_{\Delta} - L}{L}$$

After identifying stress and strain, it is possible to calculate the modules of elasticity (E) using Hooke's Law, as denoted in the following equation (Glossop 2013). The modulus of elasticity defines the tendency of a material to deform along an axis, and is essentially a measure of stiffness (Glossop 2013).

$$\sigma = E \times \varepsilon$$ Equation 2.5

The Ipswich City Council's technical drawing of a pedestrian and cyclist footpath pavement indicates that the concrete utilised is N20 concrete (Ipswich City Council, 2013). This technical drawing was approved in 2013, and is in accordance with AS 1012. N20 Concrete is a class of concrete with a strength grade of 20 MPa. The N indicates that the concrete is Normal Class concrete, and the numbers (in this case 20), indicate the strength grade in MPa (Cement Concrete and Aggregate Australia, 2007). N20 concrete generally features an aggregate size of 20 mm unless specifically requested for in a smaller aggregate size (Cement Concrete and Aggregate Australia, 2007).

Compressive strength testing for stabilised and compacted soils and similar materials features a slight difference in the equations used. The processes and procedures utilised are generally very similar (and will be explained in depth in Chapter 4 – Methodology), however the equations used to determine the compressive strength of a compacted material are different, as shown below. Australian Standard 5101.4-2008 identifies the equations as the following:

The equation given below is quite simple, as the Unconfined Compressive Strength (*UCS*) is given by multiplying the load at failure by 1273 and dividing the result by the average diameter squared.

$$UCS = \frac{F * 1273}{(D_{av})^2} \qquad \text{Equation 2.6}$$

Research regarding the usage of recycled materials has grown phenomenally in the recent years. While there is little research specifically on the use of recycled road profile, information regarding similar materials such as recycled asphalt pavement, can be utilised to gain an understanding of what may be expected. Research conducted by Arulrajah et al. (2014) indicates that Recycled Asphalt Pavement (by itself without any additives) provided strengths ranging from 100 kPa to 117 kPa, when tested in an Unconfined Compressive Strength (UCS) test. Recycled Asphalt Pavement is a material that is not very stable physically (i.e. the material falls apart and requires stabilisation), and this is evident considering that the material only provided a strength of 0.1 MPa.

When stabilised with fly ash, a Recycled Asphalt Pavement – Fly Ash mixture can produce compressive strengths of approximately 2500 kPa (Arulrajah, Horpibulsuk & Hoy, 2016). Recycled Asphalt Pavement can also be stabilised using Portland Cement (Al Harthy et al., 2002), however this defeats the purpose of utilising recycled materials, due to the amount of carbon emissions produced while manufacturing concrete (Cabezas, 2016). As identified by studies from Arulrajah et al., Recycled Asphalt Pavement /road profile can benefit from stabilisation through other virgin and recycled materials.

2.1.4 Slip Resistance

All pavements require a minimum resistance to slippage to enhance user safety, and as such a slip resistance test is required to be passed for all new pavement surfaces. There are several methods of conducting a slip resistance test including the wet pendulum, dry floor friction and wet-barefoot or oil-wet inclined platform tests. This report will focus on the wet pendulum slip resistance test, as shown in the diagram below, and described by AS 4586-2013 (Australian Standard, 2013).

The wet pendulum slip resistance test essentially utilises a rubber fitting (mimicking a shoe) on the end of a pendulum arm, to create an equal striking force with constant velocity and energy on a pavement specimen (Australian Standard, 2013). The further the pendulum travels, the lower the slip resistance of a specimen. As the pendulum travels, it pushes along a pointer, which records the height of the swing, allowing the British Pendulum Number (BPN), as shown as the measurements on the left of the device, to be recorded for each swing. The mean of the BPN's is then taken as the Slip Resistance Value (SRV) (Australian Standard, 2013).

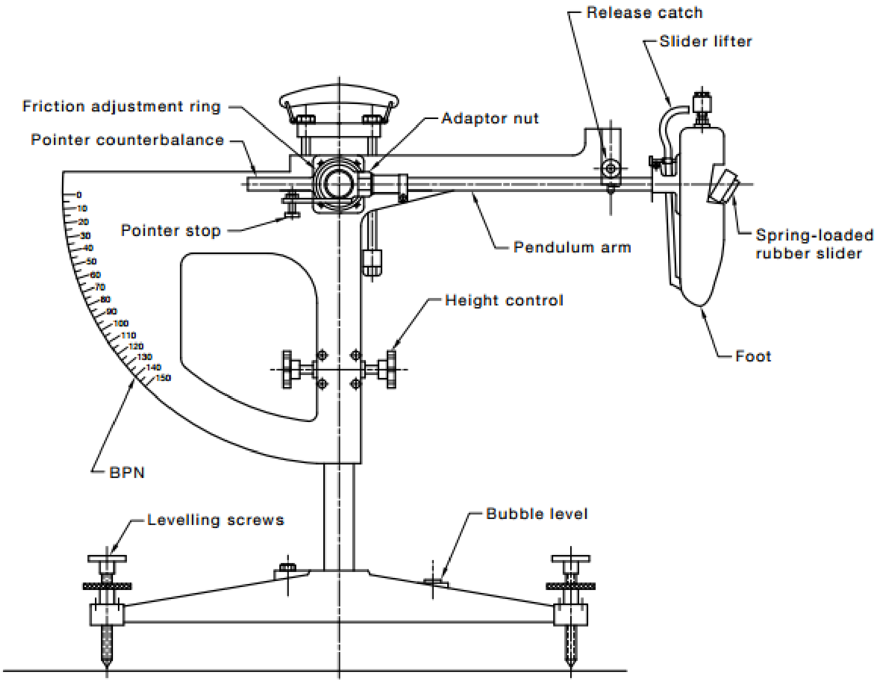

Figure 2.6: Diagram of Slip Resistance Testing Equipment (Australian Standard, 2013)

The Australian Standard Handbook 198:2014 indicates the BPN/SRV value and the classes that certain surfaces require. Stone Initiatives (n.d.) indicates that entries and access areas for public buildings while wet, fresh food areas, shopping centres and toilet facilities in public buildings require a class rating of P3; therefore, the Slip Resistance Value (SRV) should be within the range of 35 - 44 for a test using Slider 96 rubber, and 35 - 39 for a test using Slider 55 rubber. Stone Initiatives (n.d.) also identifies that external walkways, pedestrian crossings, driveways, swimming pool surrounds and communal shower areas are expected to feature a class rating of P4, with a SRV within the range of 45 - 54 for a test using Slider 96 rubber, and 40 - 44 for a test using Slider 55 rubber. Finally, external ramps greater than 1:14 and loading docks require a P5 class rating, with an SRV greater than 54 using Slider 96 rubber, and greater than 44 using Slider 55 rubber as also identified by Stone Initiatives (n.d.).

It is expected that the pavement material produced should meet the requirements of the class P4 rating, as the material is expected to be utilised for external walkways and areas such of the like. If a class P3 rating is achieved, it will be necessary to utilise methods to increase the resistance/roughness of the surface of the material. This could be similar to utilising a technique such as the broom finish that is commonly utilised to increase the slip resistance of concrete (Concrete Network, 2016).

2.1.5 Erosion

Soil erosion refers to the wearing away of a soil, especially topsoil, due to the natural physical forces of water. There are several types of erosion including rain splash, sheet, rill, gully, tunnel and bank erosion and the degree of erosion can depend on rainfall, runoff, erodibility (texture, structure, organic matter and permeability), vegetation and slope gradient and length (Ritter, 2015). In brief, Vertosols are exposed to sheet and gully erosion while Hydrosols are not prone to any types of erosion usually, but only due to the fact that they are commonly found at the base of slopes or in waterlogged areas, allowing them to avoid most of the physical forces of water. When exposed to the forces of water, Hydrosols are at high risk of erosion. Sodosols, Dermosols, and Kandosols are prone to all types of erosion, due to their high clay content or dispersive qualities. Further discussion of each soil's properties is found in Section 3 – Materials.

Dispersive soils are unstable and can break apart even in still water. These soils are at high risk of all types of erosion as they are very susceptible to water. The dispersion of soil can be classified into classes using the Emerson Class number (Cotching et al., 2009). The image below indicates how a severely dispersive soil (far right) behaves in comparison to a soil that is not considered dispersive (far left).

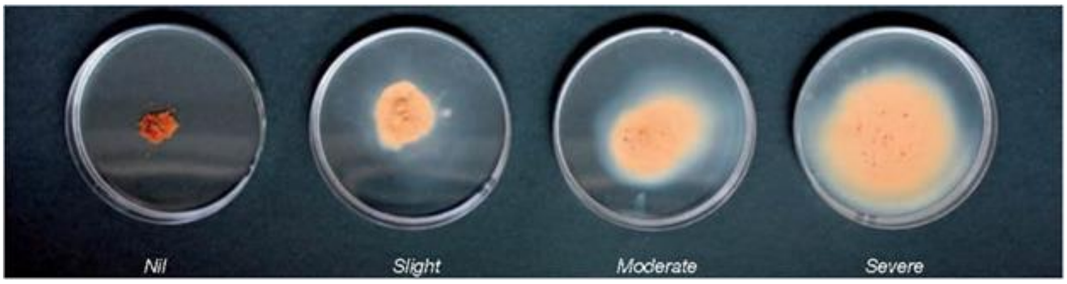

Figure 2.7: Dispersion and slaking of soil (Dairy Australia, 2016)

As shown, the non-dispersive soil (far left) shows clear boundaries of the soil, though the soil may fall apart a little, and the water remains clear. The samples shown in the image above, shows soils that range from slightly dispersive (boundaries still noticeable, water a little cloudy), to moderately dispersive (water is cloudier, boundaries are hard to see), finally to severely dispersive (the water is completely cloudy and the soil boundaries cannot be seen at all). Though dispersive soils are at risk of erosion, they are also feature high compaction qualities, also due to their susceptibility to water. This leads to the possibility that the highly dispersive soils commonly found in Ipswich (Vertosols, Hydrosols, Sodosols, Dermosols and Kandosols) may feature high compaction qualities in a mixture with PolyCom Stabilising Aid and Recycled Road Profile, which may outperform other soils. However, it will be necessary to determine if these soils are at too high of an erosion risk.

Erosion testing can be carried out both physically (according to AS 1289.3.6.3-2003 and AS 1289.3.8.2-2008), though the usage of computer modelling, such as RUSLE2 and MUSLE or through the use of Govers Equations to estimate soil erosion properties. Due to the scope of this project, computer modelling is not suitable, however, physical erosion testing may be possible, but with some modifications and if time and equipment permits. It may be plausible to utilise an Emerson Class Test, due to its simplicity (Stone, 2003), and other modified erosions tests may be carried out, to indicate if an improvement in the dispersive qualities of the soils has occurred from the inclusion of the PolyCom Stabilising Aid. These modified tests may require the soil to be submerged for 4 days, to simulate the worst condition possible, and then be exposed to a minimum volume of water expected in an annual rainfall, which is approximately 800 mL – 900 mL per mm^2 (Bureau of Meteorology, 2016) for the South East Queensland Region.

2.2 Recycled Road Profile

Roads are a fundamental part of every nation as the transportation capabilities of a country determines its economic and social value. Roads allow for the efficient transportation of products, resources, equipment and people to the places they need to be for the creation of value and usefulness. Unfortunately, roads are not designed to last forever. Not only are roads subject to an extensive range of factors that cause degradation (including weather conditions and usage), but road networks may require change over time, due to population growth or even new structural requirements. Once a road has served its purpose or is no longer appropriate for use, the road is removed, and the consequent materials are deposited as waste or stored in the hope for later use. These methods are expensive, unsustainable and wasteful in the current era where recycling and sustainability is of increasing importance. Recycling the removed road profile may provide a solution to the situation being faced. Recycling road profile not only provides another use for these materials, but further reduces the environmental impact as new resources do not need to be extracted.

Recycled road profile may provide a very efficient solution to footpath pavements. As recycled road profile comes from roads that have been removed, many of the materials were originally quite strong. Though they may no longer suitable for roads, with some renovation, these materials may meet the strength, life and other requirements, enabling the material to be used for footpaths or other pedestrian thoroughfare. By recycling road profile, Councils across the globe can reduce the negative impact of extracting valuable resources, ensure sustainable construction materials and practices for future generations and promote sustainability and recycling measures, by allowing the community to physically see the results of recycling.

Unfortunately, recycling road profile is a relatively new venture, with minimal research on its results. Though the benefits are apparent, it is unclear of the full extent of the possible problems that could arise from recycling road profile. The mixture of the recycled road profile can be very irregular as particles may range in size, texture and strength; however, this irregularity can be minimised by sieving and crushing the materials to a more uniform particle distribution. Due to the irregularity, recycled road profile can also have issues as the mixture may not hold well together, and become loose, dislodged and easily degraded. Fortunately, there is a solution to this problem as well, hopefully provided by PolyCom – a granular polymer based stabilising aid that appears to turn recycled road profile from loose aggregate to a stronger material requiring minimal maintenance.

Finally, it is important to note that the recycled road profile that is currently available for use is the product of roads that were laid in Ipswich, Australia of the time period approximately between the 1980's to 2000's. These roads would have featured different materials to roads that are constructed now, and the possible materials that might appear in the recycled road profile may vary widely, due to this, as well as due to differences in the way that profiling occurs. Because of these factors, it is necessary to identify issues that may arise, such as inconsistencies in material and material strengths. Further discussion of Road Profile will be provided in Chapter 3 – Materials.

2.3 PolyCom

PolyCom is a granular polymer-based product that functions as a stabilising aid (Roadmaker, 2014). PolyCom is distributed by SEALS Group in Queensland, and provides benefits such as increased strength, flexibility, water resistance and re-workability. It also minimises fines migration, and is easy to transport and apply. Furthermore, financial and water savings are to be made, and the product provides minimal environmental impact (Roadmaker, 2014). Due to its ease of transportation and application, PolyCom can be used to stabilise in-situ materials, rather than transporting much of these materials away. As this project is based on creating a footpath material from the soil that may already be present in the area, PolyCom Stabilising Aid seems to be well suited for application in this manner.

It is quite obvious that PolyCom features an extensive list of benefits, and currently the problems with PolyCom are minimal or inexistent. As the use and research of PolyCom in Australia is relatively new, this project will aim to reveal both the advantages and disadvantages of the PolyCom product. Nonetheless, PolyCom does provide more sustainable and environmentally friendly alternatives, and engages a much higher rate of recycling options than other traditional methods. Further discussion of PolyCom will be provided in Chapter 3 – Materials.

2.4 Soils and Sands in the Ipswich Region

Constructing a footpath or thoroughfare pavement from recycled road profile is a step towards a more sustainable construction material. Nonetheless, footpath and pavement construction can still be quite damaging to the environment, as the natural soils and sands of the area that are not used as backfill are often deposited in a different environment. This removal of natural soils and sands not only affects the environment, but can also be expensive as the volume removed increases.

As a possible solution to this, the natural soils and sands of the environment may also be used in combination with recycled road profile, to even out the pavement's mixture and provide a less expensive and less environmentally damaging solution for the natural soils and sands of the area. As this project is being undertaken within the Ipswich area and with the Ipswich City Council, the following sections will discuss the common soils and sands of the Ipswich region. The following map (Figure 2.8) identifies the locations of the common soils of the Ipswich area.

The six soils below will be utilised for testing purposes, as they are common to Ipswich.

- Vertosols - (Cracking clay soils)
- Hydrosols - (Waterlogged soils)
- Sodosols – (Sodic, alkaline and texture contrast soils)
- Chromosols – (Non-sodic texture contrast soils)
- Dermosols – (Non-cracking clay to clay loam soils)
- Kandosols – (Sandy textured soils)

A loam sand regularly utilised by Ipswich City Council will also be tested. Further information on these soils is discussed in depth in Chapter 3 – Materials. It is important to note that when referring to the soils, the surface layer is not included in the analysis or discussion, as this is vegetation and organic matter. The subsoils (taken from a depth of at least 300 mm) are the actual soils that are referred to and tested.

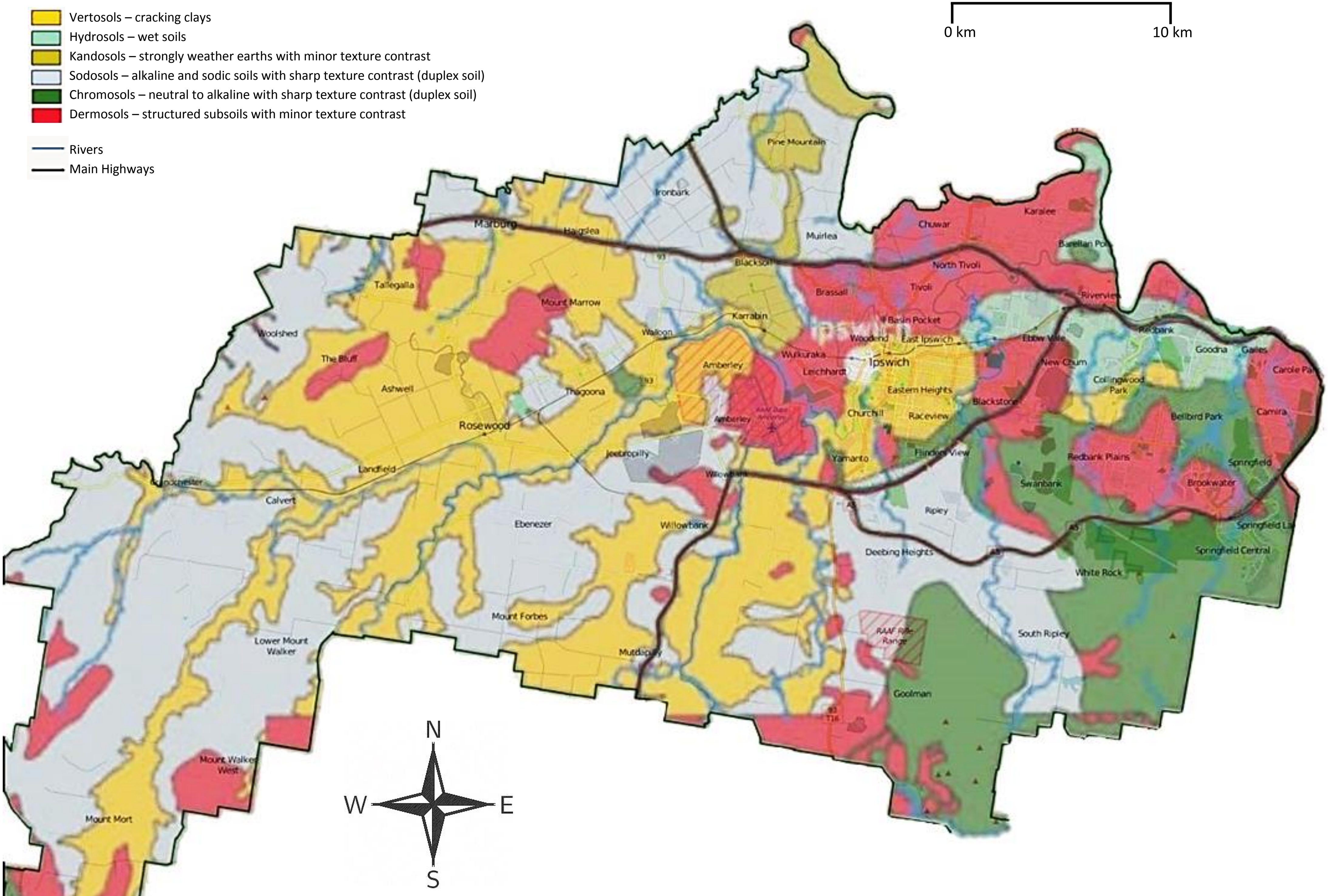

Figure 2.8: Major Soils in the Ipswich Area (Ipswich City Council 2014)

2.5 Applications and Limitations

It is essential to investigate and develop new footpath materials, such as recycled road profile footpaths, for the preservation of the environment now and in future generations, and to identify sustainable pavement solutions. Numerous studies are currently being undertaken to identify materials suitable for roads, however, not much cause is given to sustainable footpath materials (Collister et al., 2016). This project furthermore aims to move away from the conventional use of concrete as a strong footpath material, in an attempt to identify materials that are either recyclable or materials that minimise the negative effects on the environment or both.

The current applications of recycled road profile and PolyCom together are very limited. PolyCom Stabilising Aid itself is used quite extensively with other materials such as soils and gravels, especially in the northern parts of Queensland, Australia. The use of PolyCom in this manner has yielded very successful results, with minimal limitations that mainly revolve around cost. With that in mind, a small amount of PolyCom produces a large quantity of strengthened road material, which outweighs its seemingly large cost.

Conversely, recycled road profile has very limited applications currently, which has been what has prompted Ipswich City Council to consider utilising recycled road profile and other materials, in conjunction with PolyCom for the production and maintenance of certain types of roads. However, there is currently no record of the application of recycled road profile and PolyCom, with or without other materials for the production and maintenance of footpaths and other pedestrian thoroughfare. Utilising recycled road profile, PolyCom and other materials (to create a more uniform mixture) may even yield greater results when utilised for footpaths, as pedestrian thoroughfare is exposed to much less degradation, wear and tear.

For the scope of this project and due to availability of materials, the materials have been limited to PolyCom, Recycled Road Profile and soils and sands within the Ipswich region. However, the application of this project is not limited to just these materials. Many other materials could be utilised in the same manner and in conjunction with PolyCom Stabilising Aid. With adequate testing and development other materials could produce similar results, allowing application of the project on a greater basis, providing other councils and regions with more sustainable and usable options for their recycled road materials as well.

The Ipswich City Council endeavours to trial the outcomes of this project on the field. If proven successful, the solution will provide walkways, bus stops and other pedestrian thoroughfare in rural areas, and also be utilised in national parks and environmental areas.

2.6 Literature Conclusion

Recyclable materials and sustainable building practices are an ever growing issue of importance in modern construction. Researchers practicing in the public domain as well as the private arena are constantly designing and testing new materials and methods to utilise resources multiple times over and put waste materials to good use. This has been illustrated by the astounding increase in the research of utilising waste materials and recycled materials in cement and concrete mixes.

This project aims to step away from this norm and branch further by identifying possibilities that do not involve the use of concrete by utilising natural soils, PolyCom Stabiliser and recycled road profile. The review of available research regarding the characteristics exhibited by recycled materials, especially when tested for strength, will assist in the inferences, testing and discussions that will be identified in later sections of this report. The Ipswich City Council focuses on the slip resistance qualities of a footpath material, and also considers cost, environmental impact and strength properties. The next section of this report will discuss the materials in greater depth.

CHAPTER 3 – MATERIALS

3.1 Road Profile

The road profile material utilised for the testing in this research was collected from an Ipswich City Council road profile stockpile located in Rosewood, Queensland, Australia. Due to the large quantity of material required (125 kg), and reduced transportation and storage options, the road profile was sieved on site using a 19.0 mm sieve, and the passing material was collected and bagged. The 19.0 mm sieve was chosen for this process, as many of the tests to be conducted further on would require material to pass the 19.0 mm sieve, therefore; by sieving the material on site, it was ensured that enough usable material was collected.

Figure 3.1: Road Profile collected from Ipswich City Council Depot

Road profile is the term given to the material excavated from roads, using the road profiling machine. The materials that may be in the road profile can vary widely, due to the differences in the way that profiling occurs, as roads can be profiled at different depths to excavate the surface, base, subbase and possibly even the subgrade. There are also differences in road profile due to differences in the material used on roads. Over time, the material used to produce roads varies due to improvements in technology and materials, and it is also important to note that the materials used in the road also varies due to the road's purpose. These differences may cause inconsistencies in the material and in its strength and there are several different materials that could be present in the road profile, which are not limited to but may include the following.

- Bituminous materials - most likely Bitumen Class C320 and Multigrade M1000/320
  (Class 170, Class 600, Class A10E and Class A35P could also be present).
- Sand, gravel, blue metal and other common aggregates
- Subgrade materials and stabilised subgrade materials

It is difficult to pinpoint exactly which materials are present in the road profile, and assess the environmental impact of the road profile, without conducting further testing with the correct facilities that are beyond the scope of this project. It is assumed that the environmental damage caused is less than using these aggregates and bituminous materials in their new state, as the chemicals and toxins from the new materials would be largely reduced as they have been leached/washed out during the period while the road was actually in use, and also during storage (i.e. due to rain) (as confirmed by Dr Mark Lynch, 1st June 2016). The profiling process would also reduce chemicals in the road profile, if the road profile material was to come into contact with water. Furthermore, many roads that are profiled undergo the process because they have become too damaged. This degradation can be commonly caused by water, causing further chemicals and toxins to be washed away. Nonetheless, it would be important to further research and test the road profile for its environmental impact, before any field testing was to occur.

3.2 Soils and Sands in the Ipswich Region

As the six common soils and sands of the Ipswich region will be utilised in this project, it is important to consider these materials in greater depth. Road profile by itself, does not perform too well, thus optimally, these soils should assist in creating a more uniform and even mixture for the footpath material. It is important to note that when referring to the soils, the surface layer is not included in the analysis or discussion, as this is vegetation and organic matter.

Each of these soils are classed as subsoils, and are located in different regions of Ipswich. Areas to collect the six soils from were selected and preliminary safety assessments and fire ant inspections were undertaken. As these soils are subsoils, initial excavation to a depth of 300 mm – 400 mm had to be undertaken, using a pick axe and shovel. All soil to this depth was removed to ensure that organic matter and other soils did not contaminate the soil sample. Each soil was then excavated to a maximum depth of 600 mm, and the soil was removed using the pickaxe and shovel with minimal disturbance. A sample of at least 50 kg (maximum 75 kg) was retrieved for each of the six soils. The excavation sites were refilled with the suitable fill material and levelled, and each soil was stored in suitable sealable containers.

3.2.1 Vertosols - (Cracking clay soils)

Vertosols primarily contain clay within the soil, with mottled subsoils containing Calcium Carbonate (lime) and/or Manganese Nodules (Black Charcoal-like material). Vertosols have a pH level balance between neutral to a strong Alkaline, and can be classed on its most prevalent colouring to a depth of 500 mm (Ipswich City Council, 2014). Soil colouring may be categorised into grey (permanently waterlogged), brown (some organic content, some iron oxides), black (high organic matter content) and red (well drained, high iron oxide content) (Ipswich City Council, 2014). Vertosols generally occur on alluvium areas, around previous basic volcanic activity, Walloon Coal Measures and limestone sediments. This soil is quite structured, and characteristics include displaying cracks of 5 mm or greater which extend to the surface of the soil, when the soil contains little to none moisture (Ipswich City Council, 2014). The areas of Ipswich that primarily contain Vertosols are parts of Ipswich CBD, Raceview, Eastern Heights, Amberley, Rosewood, Ashwell and Mount Mort (Ipswich City Council, 2014).

Figure 3.2: Vertosols soil (oven dried) collected from Rosewood

Vertosols are rich in clay, as they are susceptible to water, including water logging, compaction and erosion (Ipswich City Council, 2010). The Vertosols soil also contains some expansive clays, prompting the soil to have strong shrink and swell properties. It is important to ensure that moisture content is well regulated, to avoid excessive shrink-swell damage (Ipswich City Council, 2014). The erosion risks of Vertosols include sheet and gully erosion on a slope of a moderate angle. Control measures for erosion consist of covering the surface of the soil and diverting the water flow to decrease velocity and separate clean water from dirty water. Other considered sediment controls include utilising a sediment basin, to catch the loose sediments (Ipswich City Council, 2010).

3.2.2 Hydrosols - (Waterlogged soils)

Hydrosols are typically quite moist, soft soils, thus being given the term waterlogged soils. Hydrosols usually remain wet for 2 or more months, continuously, seasonally or due to a waterlogged area (Ipswich City Council, 2014). The constant moisture is part of the reason for their colour, consisting of strong abundant mottling and greyish blue colours. The main cause of the grey tinge and mottling is however (Ipswich City Council, 2014), due to the lack of dissolved oxygen in the water as water logged areas tend to be quite anoxic (US Department of the Interior, 2015). Hydrosols contains some expansive clays, however the shrink-swell problem is not usually an issue, due to the wet conditions of Hydrosols (Ipswich City Council, 2014). Hydrosols will often occur in the lower slopes of sites or in areas of insufficient drainage. Hydrosols are typically found in Goodna, Collingwood Park, Ebbw Vale, Redbank, Gailes and Barellan Point (Ipswich City Council, 2014).

Figure 3.3: Hydrosols soil (oven dried) collected from Redbank

Runoff from areas that are higher may impact the soil leading to the Hydrosols gathering salt, which can give the soil a higher sodium levels. Hydrosols generally have similar properties to most soils and are quite structured, however, the constant moisture/waterlogging causes Hydrosols to be defined in their own category. Due to wet conditions and reduced biotic activity, Hydrosols topsoils also feature high to very high levels of organic matter (Ipswich City Council, 2014). As Hydrosols are often found at the lowest parts of the landscape, they are not often exposed to erosion risks caused by sheet, rill, gully or tunnel erosion. Flooding may cause a problem however, as this disturbs the soils, as Hydrosols will erode when exposed to a stream flow (Ipswich City Council, 2010).

3.2.3 Sodosols – (Sodic, alkaline and texture contrast soils)

The Sodosols surface is usually hard setting with a colouration of brown to dark grey. Sodosols surface pH levels can very between neutral to strong acidity levels. The layer between the surface soil and the subsoil is a pale sandy layer similar to Kurosols (Ipswich City Council, 2014). The clay subsoil of Sodosols soil can feature colours ranging from red (well drained, high iron oxides) or brown (organic content and some iron oxides) through to yellow (moderate to poor drainage with high iron oxides) or grey (waterlogged) and can be quite mottled (Ipswich City Council, 2014).

Figure 3.4: Sodosols soil (oven dried) collected from Ripley

The subsoil typically features strong alkaline levels while containing dense soil sodium levels. Due to this, Sodosols can be quite dispersive (Ipswich City Council, 2010). Sodosols are susceptible to erosion due to the subsoil dispersion, causing Sodosols to be prone to sheet, tunnel and gully erosion (Ipswich City Council, 2010). However, Sodosols contains little to no expansive clays, providing minimal to no shrink-swell problems (Ipswich City Council, 2014). Sodosols are typically found in parts of South Ripley, Ripley, Deebing Heights, Ebenezer, Iron Bank, Muirlea, Woolshed and Lower Mount Walker (Ipswich City Council, 2014).

3.2.4 Chromosols – (Non-sodic texture contrast soils)

Chromosols are similar to Sodosols, in terms of being texture contrast soils. Chromosols features a sandy to loamy surface and a sandy subsoil (Ipswich City Council, 2014). Chromosols can appear on flat sedimentary areas or on sloping land, and the topsoils can be loose to hard setting with soil colouration ranging from dark brown (organic content and some iron oxides) to dark grey (waterlogged soil). The structure of the surface soils is generally quite weak (Ipswich City Council, 2014).

Similar to Sodosols, the Chromosols soils feature a pale subsurface layer, separating the subsoil and surface. Chromosols contains little to no expansive clays, this giving it minimal to none shrink-swell problems (Ipswich City Council, 2014). However, Chromosols are susceptible to erosion, especially sheet, tunnel and gully erosion even on shallow slopes (Ipswich City Council, 2010). Chromosols can typically be located in Springfield Central, Springfield, Swanbank, Bellbird Park and Goolman (Ipswich City Council, 2014).

Figure 3.5: Chromosols soil (oven dried) collected from Springfield

Chromosols subsoils colouration ranges from red (well drained, high iron oxides) to brown (organic content and some iron oxides) to black (high organic matter) as well as grey (waterlogged). Mottling occurs where the subsoil is imperfectly drained, but is more frequent in heavier clays. Chromosols subsoils commonly feature a pH level of neutral or low levels of acidic and alkaline, and no salinity (Ipswich City Council, 2014).

3.2.5 Dermosols – (Non-cracking clay to clay loam soils)

Dermosols are clay rich soils, with fairly sound structure, and sometimes stony slopes. Surface colours tend to be brownish black to black, indicating high organic matter content.

Dermosols topsoil acidity levels can vary between neutral pH levels to slight amounts of acidity (Ipswich City Council, 2014). When Dermosols are found on steeper slopes the topsoil tends to be shallow, and conversely, when found on flat land, the Dermosols topsoil is quite deep (Ipswich City Council, 2014). The areas of Ipswich that primarily contain Dermosols are Carole Park, Camira, Redbank Plains, Blackstone, New Chum, Riverview, Chuwar, North Tivoli, Karalee, Basin Pocket, Brassall, Wulkuraka, Leichhardt and Mount Walkers West (Ipswich City Council, 2014).

Figure 3.6: Dermosols soil (oven dried) collected from Camira

The Dermosols subsoils consist of a clay loam to a medium clay, with colours varying from grey (waterlogged) to brown (some organic content, some iron oxides) and black (high organic matter content) (Ipswich City Council, 2014). Dermosols subsoil acid levels can be between neutral pH levels to moderately alkaline pH levels. The Dermosols characteristics generally have free drainage properties that allow it to drain freely (Ipswich City Council, 2014).

Dermosols contains little to no expansive clays, providing it with minimal to no shrink-swell problems (Ipswich City Council, 2010). However, Dermosols feature a very high risk of erosion and dispersion due to the clay-rich content of the soil, even on a low angle slope if left exposed to natural weather elements (Ipswich City Council, 2010). Therefore, surface cover should be maintained in order to reduce erosion, and drainage should be in place to reduce water velocity and to separate clean water from contaminated water (Ipswich City Council, 2010).

3.2.6 Kandosols – (Sandy textured soils)

Kandosols soil features surface properties ranging from firm to loose surface soil, with a texture of sandy loam that may contain clay content that increases with depth (Ipswich City Council, 2014). Kandosols topsoil is commonly dark brown or grey brown, indicating that some organic matter content is present. Kandosols are porous and can be crumbled easily with no structure (Ipswich City Council, 2014). The acidity levels can vary significantly, as surface soil may feature natural pH levels, whereas the deeper layers of the subsoil can be highly acidic, featuring pH levels of 5.5 (Ipswich City Council, 2014).

Figure 3.7: Kandosols soil (oven dried) collected from Pine Mountain

The subsoil of Kandosols includes sandy clays that usually exist in the deeper parts of the subsoil. The colour of the subsoil is dependent on the parent material and drainage qualities of the subsoil, featuring red (well drained with iron oxides) to brown (organic content and iron oxides) or even yellow (poorly or moderately drained with high iron oxide content) (Ipswich City Council, 2014).

Kandosols contains little to no expansive clays, thus providing it with minimal to no shrink-swell problems (Ipswich City Council, 2014). Unfortunately, Kandosols have a very high risk of erosion even on a low angle slope if left exposed to the elements (Ipswich City Council, 2010). Surface cover should be maintained in order to reduce erosion, and drainage should be in place to reduce water velocity and to separate clean water from contaminated water (Ipswich City Council, 2010). Kandosols are generally found in areas such as Pine Mountain and Blacksoil (Ipswich City Council, 2014).

3.2.7 Loam Soil (Sand)

The sand utilised for testing was also collected from the Ipswich City Council depot at Rosewood. As the aim of this research was to develop a cheap material, the loamy soil/sand available from Ipswich Council was most suitable as this was the cheapest sand material that the Council regularly utilises. A sample of at least 60 kg of sand was collected and bagged. Unlike the other 6 soils, the sand will not be mixed with road profile. Instead, the sand is hoped to be utilised as a protective layer on top of the road profile and soil mixture, if need be.

Figure 3.8: Loam soil / sand (oven dried) collected from Rosewood

3.3 PolyCom

As stated in Chapter 2, PolyCom is a granular polymer-based product that functions as an effective stabilising aid (Roadmaker, 2014). Polymers are compounds that are bound together in long repetitive chains, and can be natural or man-made, such as rubber and plastics respectively (Johnson, 2016). PolyCom does not require curing such as conventional materials, but is rather just mixed into a material and begins to act on compaction, with a period of 3 -7 days given to allow the PolyCom to be most effective (Roadmaker, 2014). This allows in situ materials to be utilised, rather than being transported away without purpose. Thus, PolyCom can be used to stabilise almost any material that is commonly utilised in road construction and earthworks (Roadmaker, 2014). PolyCom can be utilised with naturally occurring subgrade materials to aggregates prior to sealing work, and features application as sealed and unsealed roads, hardstands, mine site haul roads, airstrips, access roads and shoulders, among others (Roadmaker, 2014).

Figure 3.9: PolyCom Stabilising Aid

Only 2 kilograms of the PolyCom product is required to stabilise 50 m^3, or 100 tonnes of material (Roadmaker, 2014). Approximately 750 grams of Dry PolyCom Powder was provided by Shane Donovan of SEALS Group Qld Australia, to assist in this project. This granular based polymer product is said to be effective in improving road material, featuring benefits such as the following:

1. **Increased strength**:
   PolyCom increases the strength of the material by increasing layer density and heightening the resilient modulus, resulting in creating higher CBR values.

2. **Increased flexibility**:
   Material flexibility is increased by delivering increased strength to the natural mechanical interlock of the host material and allowing for polymer bonding of the particles.

3. **Increased water resistance**:
   By increasing density and reducing void spaces, PolyCom minimises the chance of water seepage into the stabilised layer.

4. **Minimisation of fines migration**:
   Due to increased density and cohesiveness of the material, PolyCom reduces the migration of fines through layers.

5. **Increased re-workability**:
   PolyCom features no set curing time and an indefinite life of its materials. This enables sites to store as much material as required and use when needed.

6. **Ease of transportation:**
   As PolyCom is produced in concentrated 2 kg bottles, it is very easy to transport. Each bottle stabilises 50 m^3 and can be applied at 0.002%. PolyCom is not only easy to transport, but is also cheaper to transport too.

7. **Ease of application**:
   Due to the dry spreading of the product and simple blade mixing through the host/in situ materials, PolyCom features easy application. Once spread, all that is required is the regular road construction equipment such as graders, rollers and a water truck.

8. **Water savings:**
   PolyCom reduces the moisture evaporation rates of treated material considerably, lowering most materials to feature an Optimum Moisture Content of 30% or less. Moisture loss during construction is critical in hot climates or areas where water is scarce. Furthermore, PolyCom treated roads require significantly less maintenance, further reducing the need for water. It has been proven that PolyCom provides an 80% reduction in water usage.

9. **Environmental Impact:**
   Being both non-toxic and OH&S compliant, PolyCom has a very minute impact on the environment. It is approved for use in water catchment areas and provides a 90% reduction in greenhouse gas emissions.

10. **Financial savings:**
    Apart from the increased strength, flexibility and other improved attributes, as well as the reduced environmental impact; PolyCom furthermore features significant financial savings. Costs of the product itself are minimal in comparison to traditional materials, and transportation of materials and maintenance of roads is phenomenally lowered.
    (Roadmaker, 2014)

As stated previously, PolyCom apparently provides many benefits, and its weaknesses are said to be minimal. This project aims to reveal the advantages and disadvantages of the PolyCom product, in terms of stabilising a footpath material. It is important to note that this project will not focus on PolyCom itself, but rather aims to identify if this stabilising agent can assist in providing the benefits needed to ensure that the footpath material can meet the requirements.

3.4 Concrete

Finally, for the purposes of providing a more accurate comparison (by using the same equipment for all testing), concrete samples were also prepared. The concrete samples were prepared using two 20 kg bags (40 kg total) of pre-mixed Bastion brand N25 Concrete. The mixture was prepared according to manufacturer instructions (for the amount of water required) and in accordance with the AS1012 (for mixture preparation, sample preparation and testing).

Figure 3.10: N25 Bastion Pre-Mix Concrete

CHAPTER 4 – METHODOLOGY

4.0 Methodology Overview

The following chapter will discuss the methods and procedures utilised to produce the results for the following areas:

- Particle Size Distribution
- Optimal Moisture Content (OMC) and Maximum Dry Density (MDD)
- California Bearing Ratio (CBR)
- Unconfined Compressive Strength (UCS) (for compacted soil samples)
- Preparation of Concrete samples and Slump test
- Compressive strength (for concrete samples)
- Slip resistance

It is necessary to identify these procedures to allow for comparison in testing procedures and comparison of results, and to increase the reliability and accuracy of the results obtained.

The particle size distribution of each soil was conducted as a test to classify the soils. After conducting the particle size test, the Optimal Moisture Content (and Maximum Dry Density) test was performed using the Modified Proctor Compaction method (AS 1289.5.2.1). These Proctor tests were completed to determine the correct moisture content that each soil required, to achieve the best compaction with minimal voids, for further tests such as the CBR and UCS tests.

After determining the optimal moisture content for each soil and for road profile and sand, the next task was to determine the optimal mix ratio of road profile to each different soil. This was undertaken by performing 19 CBR tests, in a modified manner. Each of the four remaining soils (as two clayey soils were omitted) were tested at the following mixes.

- 100% Soil – 0% Road Profile (1 sample for each soil)
- 75% Soil – 25% Road Profile (1 sample for each soil)
- 50% Soil – 50% Road Profile (1 sample for each soil)
- 25% Soil – 75% Road Profile (1 sample for each soil)
- 0% Soil – 100% Road Profile (1 sample)

Each mix was tested, and the highest performing percentage was taken to be the optimal percentage of road profile for that particular soil.

The next task was to conduct 16 CBR tests, using the optimal road profile mixes. CBR tests were conducted according to standard without any modifications, and each specimen was soaked for 4 days. This set of testing yielded the correct CBR values for the soil and road profile mixtures. The following tests were performed.

- CBR tests of each soil without road profile and without PolyCom (this enables comparison of improvement/reduction in CBR when compared to specimens that have soil and road profile without PolyCom)

- CBR tests of each soil at its optimal road profile mix without PolyCom (this enables comparison of improvement/reduction in CBR when compared to specimens with soil, road profile and PolyCom, and specimens which are soil only)

- CBR tests of each soil at its optimal road profile mix with PolyCom Stabiliser (this enables comparison of improvement/reduction in CBR when compared to specimens that have soil and road profile without PolyCom)

As the optimal road profile and soil mixes were known, the Unconfined Compressive Strength Test and the Slip Resistance tests could be conducted during the waiting periods of the CBR tests (curing and soaking times for specimens). The Unconfined Compressive Strength and Slip Resistance tests were conducted on samples that did have PolyCom Stabiliser.

The compressive strength tests for the concrete samples were conducted 28 days after the samples were poured. As the concrete samples were only utilised for comparison purposes, the preparation, pouring, slump test and compressive strength tests were straightforward and did not required many modifications.

4.1 Particle Size Distribution

AS 1289.3.6.1-2009 Methods of testing soils for engineering purposes Soil classification tests— Determination of the particle size distribution of a soil— Standard method of analysis by sieving

The particle size distribution test is important in classifying the soils for engineering and design purposes, as this provides an understanding of how fluids move through the soil (for draining purposes especially) (ASTM International, 2014). For the purposes of this project, the particle size distribution was also important for another reason. As some soils feature much finer particle sizes, it is hoped that a relationship can be shown between particle size and the optimal amount of road profile that is able to be utilised with a soil (i.e. soils with finer particles sizes should feature higher amounts of road profile, in comparison with soils of course particle sizes which should feature less).

During the particle size distribution, problems were encountered with two of the six soils. These two soils (Vertosols and Hydrosols) featured very high clay contents and high moisture contents naturally, causing the soils to be very sticky. Due to this, an attempt was made to crumble the soils and dry them out, to enable them to pass through the sieves, but this process distorted the results of their tests.

PARTICLE SIZE DISTRIBUTION PROCEDURE:

1. Soil samples were prepared in accordance with AS1289.1.1-2001, and a subsample of 5 kg was utilised for the particle size test, as required. This subsample was then divided into 2 subsamples, as the mechanical sieve shaker available was unable to take more than 3 kg's of soil at a time.
2. The total mass of the soil for the subsample was measured.
3. Each sieve was thoroughly cleaned before the test with a clean rag and brush, to ensure no other particles were present, and the size of the sieve was recorded. Sieves of the following sizes were utilised during the sieving process:

Table 4. 1: Sieve sizes used

Course Gravel	Medium Gravel	Fine Gravel	Course Sand	Medium Sand	Fine Sand
37.5 mm	19.0 mm	6.70 mm	2.36 mm	600 µm	150 µm
26.5 mm	13.2 mm	4.75 mm	1.18 mm	425 µm	75 µm
	9.5 mm			300 µm	

4. The first subsample of each soil was loaded into the largest sieve of the sieving machine. The mechanical sieve shaker (as shown to the left) was operated for 5 minutes.

Figure 4.1: Mechanical Sieve Shaker – USQ Lab

5. The mass of the soil retained on each sieve was measured and recorded, and the sieves were cleaned thoroughly.
6. Steps 2 – 5 were repeated for the second subsample of each soil; however, this time the mechanical sieve shaker was operated for 10 minutes.

4.2 Determination of Optimal Moisture Content and Maximum Dry Density

AS 1289.5.2.1-2003 Methods of testing soils for engineering purposes - Soil compaction and density tests—Determination of the dry density/moisture content relation of a soil using modified compaction effort

It is necessary to determine the optimal moisture content and maximum dry density of a soil, to determine the correct amount of water to mix with soil portions. This ensures that when compaction occurs, the soil can be compacted in the most effective manner, leaving minimal voids, so that further testing of the soil is as accurate as possible.

During the compaction testing of the soils, problems were encountered with two of the six soils. These two soils (Vertosols and Hydrosols) featured very high clay contents and high moisture contents naturally, causing the soils to be very sticky. As the natural moisture contents of these two soils were approximately 20%, the soils first had to be dried. This caused the clay soils to become very hard in the oven (especially Vertosols) and the soils then had to be broken down to a usable size, to pass through the 19.0 mm sieve (as per set parameters).

Figure 4.2: Imperfections in Vertosols soil compacted into Proctor mould

Further problems were encountered during the compaction process, as the soil would squeeze up the sides of the mould as it became compacted (especially the softer clay Hydrosols). Even though extensive testing was conducted, the clayey soils still featured many voids, regardless of moisture content. Vertosols were very difficult to gain proper results from, as the soil was very hard. At this point, a decision was made to omit these two clayey soils from further testing, as both Vertosols and Hydrosols featured poor workability, and did not fare well during the compaction process nor the particle size distribution analysis. Due to time limitations, and the likelihood of shrinkage and swelling problems, these two soils were completely omitted from testing beyond this point.

COMPACTION PROCEDURE:

1. The soil samples were prepared in accordance with AS 1289.1.1 and a 20 kg sample of each soil was utilised for the testing procedure.
2. Soil, sand and road profile materials were screened through the 19.0 mm sieve. (As all materials passed the 19.0 mm sieve, Test Mould A was able to be used).
3. After screening through the sieve, each material was split into 8 equal portions. Each portion was then stored in an airtight sealable storage bag, and each bag was weighed, with the weight recorded on each bag for control purposes.

4. It was decided that an initial test should be conducted using 1 portion from each soil, to determine the initial moisture content of each soil.

5. Before undertaking any compaction, the correct equipment was gathered, and the Proctor mould (Diameter: 105 mm, Height 115 mm), collar, baseplate and rammer were inspected, prepared and measured. After recording the weight of the mould and baseplate, the mould, collar and baseplate were all assembled.

6. The specimen was then compacted into 5 equal layers. Each layer received 25 uniformly distributed blows from a 4.5 kg rammer falling from a height of 450 mm (as per the modified compaction method).

   The compacted height of soil in each specimen was:

   a. 23 mm to 28 mm in the 1st layer,
   b. 47 mm to 52 mm in the 2nd layer
   c. 70 mm to 75 mm in the 3rd layer,
   d. 93 mm to 98 mm in the 4th layer, and
   e. 116 mm to 120 mm in the 5th layer.

7. After compaction was completed, the collar was removed from the mould and the surface of the mould was trimmed using a metal straightedge.

8. The mass of the mould, baseplate and specimen were subsequently measured, and the specimen was removed from the mould, using the correct demoulding equipment.

Figure 4.3: Demoulding soil sample from Proctor mould

9. Immediately after demoulding the specimen, 3 small samples of soil were taken from the compacted specimen, from the top, middle and bottom. The small samples (of approximately 50 g) were placed into a small tin, measured and dried in the oven for

24 hours at 105 °C – 110 °C, to enable the determination of the moisture content in accordance with AS 1289.2.1.1. After being completely dried, the sample was measured again to determine the moisture content (%) of the soil.

10. By determining the moisture content and maximum dry density of the first portion of each soil before adding or removing water, an estimate was formed of how much moisture was required to be added or removed, as AS1289.5.2.1 advises that most soils generally have an OMC of 10%. The Standard requires that there be 2 results below the OMC, 1 approximately at the OMC and 1 over the OMC. Using this information, 3 - 4 portions of each soil were prepared.
11. Portions that required the reduction of water were dried for 24 hours in the oven at 105 °C – 110 °C. Water was then added to each portion (normal and oven dried) ensuring that equal increments were present between each portion. The portion was mixed thoroughly and allowed to cure for a minimum of 2 hours, to ensure that the water was uniformly distributed through the soil.
12. Steps 6 – 9 were repeated for each portion, to obtain the dry density curve for each soil.
13. If the points plotted were not sufficient to provide the curve, further portions were utilised and prepared as stated in Step 11. Steps 6 – 9 were then repeated for that portion, to ensure a sufficient curve was obtained.

4.3 California Bearing Ratio (CBR) Testing

AS 1289.6.1.1:2014 Methods of testing soils for engineering purposes - Soil strength and consolidation tests—Determination of the California Bearing Ratio of a soil—Standard laboratory method for a remoulded specimen

CBR PROCEDURE:

1. The soil samples were prepared in accordance with AS 1289.1.1. The amount of water required for the sample was thoroughly mixed with PolyCom (0.002% of the total sample weight). The PolyCom and water were mixed thoroughly for 10 minutes and allowed to cure for 2 hours. After 2 hours, the soil and road profile (in their correct proportions) were mixed with the PolyCom and water mixture, to bring the soil to 85%

of the soil's original OMC. The test portions were thoroughly mixed and allowed to cure for a minimum of 2 hours.

2. The mass of the equipment was measured (mould, baseplate, etc.) and all the equipment was thoroughly inspected and cleaned. The CBR moulds utilised all met the dimension requirements of 152 mm for diameter and 178 mm for height.
3. The mould was assembled in the following process:
   - A piece of clean A4 paper (replacement for filter paper) was placed on top of the baseplate.
   - The space disc was then placed onto the paper (hole side down), and a circular piece of baking paper was placed onto the spacer disc.
   - The baking paper was utilised to stop the compacted soil from sticking to the spacer disc, to ensure that the test face of the specimen was not disrupted.
   - The mould was then slotted into the baseplate and spacer disc and secured in place by wing nuts.
   - The collar was then slotted onto the top of the mould and also secured into place by wing nuts.
4. The soil was placed into the mould and compacted in a uniform manner.

   Specimens received 44 blows per layer (in a pattern of 8 blows around the perimeter and 3 blows in the middle) for 5 layers as per the modified compaction in AS 1289.5.2.1.

   The depths of each layer were checked to ensure that they were as per the depths set out in this standard.
5. The collar was removed from the mould and the specimen was trimmed utilising a straightedge.
6. The baseplate, spacer disc, A4 paper and baking paper were then removed, and the mould and specimen were weighed, and the mass recorded. The mould was then inverted, and secured to the baseplate again.
7. Samples that contained PolyCom were allowed to cure for 3 days ambient room temperature while in the mould, as per the PolyCom Stabiliser requirements. Samples without PolyCom did not require curing, and proceeded to Step 8.

8. A surcharge of 4.5 kg was applied (placed in the mould on top of the specimen) and the mould was submerged in water for 4 days, with water allowed to freely access the top and bottom of the mould.
9. Soaked specimens were removed from the water after 4 days, and tilted to remove surface water, then placed on a draining grate for 15 minutes. After 15 minutes, the surcharge was removed and the specimen, mould and baseplate were measured. The penetration test was performed immediately after.
10. The penetration piston and machine were calibrated accordingly, and the 4.5 kg surcharge was reapplied to the soaked specimens. The electronic force measuring and displacement measuring devices were set to zero.
11. The load was then applied at a constant rate of penetration of 1.0 mm per minute, using the manual machine (10 rotations per minute). Load and displacement readings were recorded by the automatic reading machine, which produced a data file that was saved to a USB device.

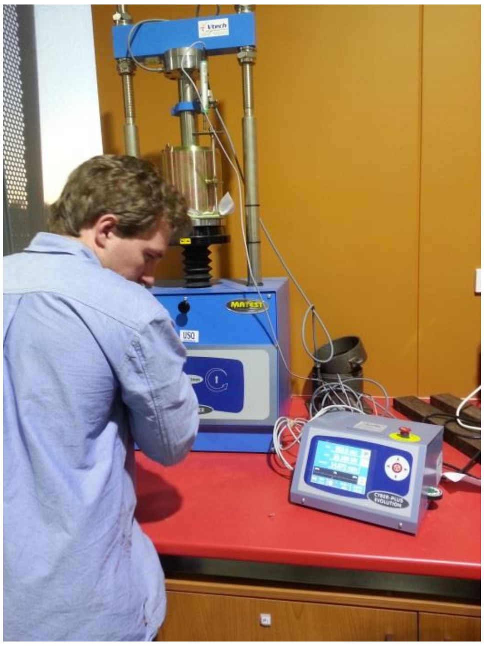

Figure 4.4: CBR Test in progress – USQ Lab

Figure 4.5: Soil specimen in mould after CBR test

12. After reaching 12.6 mm penetration, the test was stopped. The specimen was removed from the machine, and subsequently demoulded. A sample was taken from the top 30 mm layer, to determine the moisture content of the specimen as per AS 1289.2.1.1.

4.4 Unconfined Compressive Strength (UCS) Test

AS 5101.4-2008 Methods for preparation and testing of stabilized materials
Unconfined compressive strength of compacted materials

The UCS test was conducted to provide a compressive strength for the soil specimens. PolyCom Stabilising Agent is classified as a polymer binder, and unfortunately, this particular standard did not specify a curing time for polymer binders. Due to this, the procedure outlined by SEALS Group for curing times was utilised.

Some adjustments were made as certain problems were encountered. The procedure outlined by SEALS Group for specimens with PolyCom indicated that specimens should be allowed to sit within the mould for 3 days. The first set of testing using this procedure yielded significantly lower results, as the core of the specimens was still damp.

The decision was made to allow the specimens to cure for a further 4 days after being removed from the mould. The second set of testing then utilised this modified procedure, and yielded significantly different results, as the unconfined strength had doubled, as the specimen was not so damp inside.

UCS PROCEDURE:

1. The materials were prepared as per AS1289.1.1. Materials were sieved through the 19.0 mm sieve and the materials that passed were split into 2 portions, ensuring that each portion was at least 3 kg. The amount of water required for the sample was thoroughly mixed with PolyCom (0.002% of the total sample weight). The PolyCom and water were mixed thoroughly for 10 minutes and allowed to cure for 2 hours. After 2 hours, the soil was mixed with the PolyCom and water mixture, to bring the soil to 85% of the soil's original OMC. The test portions were thoroughly mixed and allowed to cure for a minimum of 2 hours.
2. The Proctor moulds (Diameter: 105 mm, Height: 115 mm), baseplate and collar were cleaned, inspected and assembled and the specimen was compacted according to AS 1289.5.2.1-2003.
3. After compaction the collar was removed and the specimen was trimmed using a metal straightedge. The remaining material was utilised to determine the moisture content in accordance with AS 1289.2.1.1.
4. The mass of the mould and specimen were measured and recorded.

5. The specimen was demoulded immediately and allowed cure for 7 days in air (room temperature ranging between 20 °C – 25 °C).

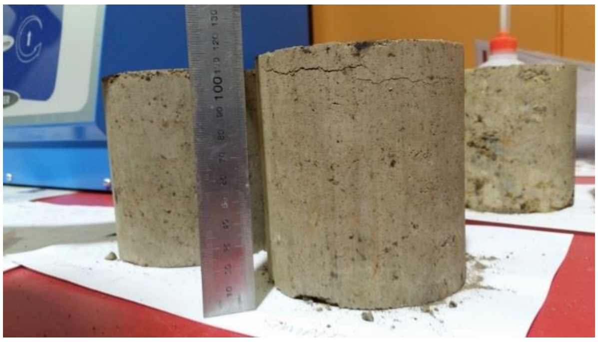

Figure 4.6: Soil specimen for curing (UCS test)

Figure 4.7: Soil specimens for 7 days of curing (UCS test)

6. After curing, the compression testing procedures commenced immediately. The specimen was weighed, and the average diameter of the specimen was measured and recorded.
7. The test specimen was placed on the lower bearing block of the compression testing machine, ensuring that the vertical axis of the specimen was aligned with the centre of the upper block. The upper bearing block was gently brought to bear on the specimen to ensure uniform seating.

8. The load was applied at a constant rate of 2.4 kN/s until failure. The load at failure was recorded to the nearest 0.5 kN.
9. The moisture content of the specimen was determined by drying the specimen in accordance with AS1289.2.1.1.

Figure 4.8: Soil specimens in UCS test machine

4.5 Slip Resistance – Wet Pendulum Test

AS 4586-2013 Slip resistance classification of new pedestrian surface materials

WET PENDULUM METHOD

It is necessary to ensure that pedestrian thoroughfare features a surface with enough friction, to reduce the possibility of accidents due to slipping on the surface while it is wet. The slip resistance standard (Wet Pendulum Method) was utilised to determine the slip resistance qualities of the soil specimens. The specimens were not subjected to any methods that would create a rougher surface, to ensure that the specimen's surface was as smooth as possible (to obtain the worst result possible).

- As no slip resistance mould was available, a 100 mm x 200 mm steel mould with removable baseplate was made specifically for this test. The mould meets the minimum dimension requirements of 100 mm x 150 mm as set out in Paragraph A6 of this standard.
- As the test required a level surface, it was decided that a flat piece of wood (98 mm x 198 mm) with a smooth surface needed to be inserted into the mould on top of the soil, to achieve the level surface required.
- It was also decided that compaction would be best achieved by using 2 Manual Marshall Compaction hammers, with free falling weight of 4.53 kg, and falling height of 457 mm. Utilising two hammers side by side enabled level compaction, as the second hammer provided the most adequate counterweight solution, to ensure that the soil did not compact on one side, only to be pushed out on the other side.

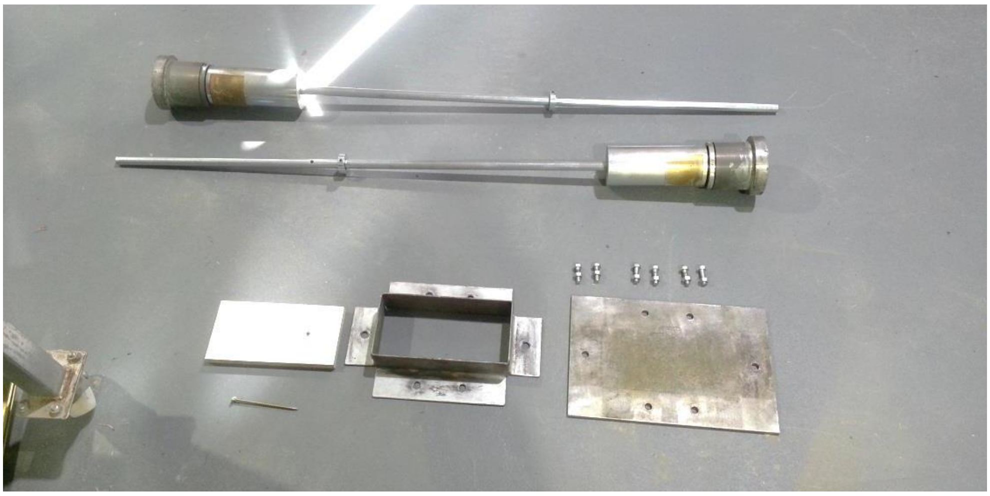

Figure 4.9: Equipment used for Slip Resistance test

SLIP RESISTANCE PROCEDURE:

1. The materials were prepared as per AS1289.1.1. Materials were sieved through the 19.0 mm sieve and the materials that passed were split into 5 portions, ensuring that each portion was at least 1 kg. The amount of water required for the sample was thoroughly mixed with PolyCom (0.002% of the total sample weight). The PolyCom and water were mixed thoroughly for 10 minutes and allowed to cure for 2 hours. After 2 hours, the soil was mixed with the PolyCom and water mixture, to bring the soil to 85% of the soil's original OMC. The test portions were thoroughly mixed and allowed to cure for a minimum of 2 hours.
2. After the materials had cured, the specimens were compacted. The specimens were compacted using 2 manual Marshall compaction hammers, with each hammer providing 20 blows (40 blows in total).
    a. After the first 10 blows, the depth of the soil in the mould was measured at different points around the mould, to ensure that the specimen was being compacted in a uniform manner to achieve a level surface.
    b. After another 10 blows, the depth of soil was measured again.
    c. After the remaining 20 blows, the depth of the specimen was measured again, to ensure that the specimen's surface was level.
3. After the specimen was compacted and measured, the depth was recorded and the specimen was weighed and removed from the mould. The specimen was allowed to cure for 3 days, as per PolyCom guidelines.
4. The machine and sliders were prepared, adjusted and calibrated as per this standard. Before conducting the test, the head of the instrument was raised, to check that the pendulum was able to swing clear and ensure that the zero setting was correct.
5. The pendulum arm and specimen were aligned correctly, to ensure that the arm had the correct surface length to travel across.
6. The surface of the test specimen was saturated with potable water, to the point that the surface was visibly wet during the entirety of the test. The slider was also sprayed with potable water.
7. The pendulum was operated for a minimum of five swings, and the specimen was rewetted before each swing. The machine was zeroed before each swing, and the slider was cleaned and rewetted as well.

Figure 4.10: Soil specimens in Slip Resistance test setup

8. The BPN from each swing was recorded, and the test continued until the last three readings differed by no more than three units. The SRV was calculated and the class determined.
9. After conducting the test, the head of the instrument was raised, to check that the pendulum was able to swing clear and ensure that the zero setting was correct.

4.6 Concrete Preparation (in Laboratory)

AS 1012.2:2014 Methods of testing concrete

<u>Preparing concrete mixes in the laboratory</u>

2 bags of 20 kg Bastion pre-made concrete mix, water and all equipment (scoops, mixer, etc.) were gathered and checked. Materials to be used were already at room temperature (20 °C – 26 °C) and an electric motor driven mixer was utilising during the mixing process.

1. The mixer was wetted and excess water drained.
2. The mixer was charged with 40 kg concrete mix and 4.2 L of water was added to the concrete mix, as per manufacturer instructions.

3. The mixer was operated for 30 seconds and then stopped, to check the consistency of the mix.
4. The mixer was operated for a further 2 minutes, and another 800 mL of water was added during the 2 minutes.
5. The mixer was stopped for 2 minutes, and then operated for a further 2 minutes.
6. The mixer was stopped for 3 minutes. During this time, the slump test was carried out, as discussed in Section 4.7. The slump was correct at this stage.
7. The mixer was operated for a further 2 minutes. At the end of the 2 minutes, another slump test was carried out. As the second slump test was also correct, the mixture was then classed as a sample.

4.7 Slump Test

AS 1012.3.1:2014 Methods of testing concrete

Determination of properties related to the consistency of concrete—Slump test

The slump test is used as a method to determine the consistency of fresh concrete, to ensure that the mixture created is acceptable as a sample.

1. The internal surface of the cone and the baseplate was inspected to ensure that they were free of concrete, and were wiped with a damp cloth.
2. The cone and baseplate were placed in a clean, flat tray and secured firmly, to ensure that movement did not occur during the test.
3. The cone was filled in three equal layers, each approximately one third of the height of the mould.
4. Each layer was rodded with 25 strokes of the rod, in a uniformly distributed matter. Filling and rodding the specimen was completed in 3 minutes without interruption.
5. After the top layer was rodded, the surface was levelled and any material at the base of the cone was removed. The cone was removed by raising it slowly and in a vertical motion in 2 - 4 seconds.
6. The slump was immediately measured, by determining the difference between the average height of the top surface of the concrete and the height of the cone (300 mm). The slump was measured to be 65 mm at the first test, and 55 mm at the final test, and in both instances the slump exhibited typical slump properties. As the slump was

satisfactory, the mixture was then acceptable as a sample.

The slump of the mixture was considered acceptable, and the mixture was able to be used for moulding purposes. As the slump measurement was less than 100 mm, the slump was recorded to the nearest 5 mm. The slump test resulted in a slump of 55 mm for the mixture and the type of slump obtained was a typical slump.

4.8 Concrete moulding

AS 1012.8.1:2014 Methods of testing concrete

Method for making and curing concrete

To ensure that a full range of comparable results was available, the decision was made to utilise both the typical concrete moulds and the Proctor moulds. The compaction effort required for soil in a Proctor mould is known, but the compaction effort required for soil in a 100 mm x 200 mm concrete mould is unknown. As the Unconfined Compressive Strength specimens were created using the Proctor mould, it was appropriate to create concrete specimens in both the Proctor moulds for comparability and the typical concrete moulds for control purposes.

1. Concrete moulds (Diameter: 100 mm, Height: 200 mm) and Proctor Moulds (Diameter: 105 mm, Height: 115 mm) were inspected and cleaned.
2. Concrete moulds were prepared by ensuring that the two halves were locked, and applying a thin coat of mould oil using a soft brush. Proctor moulds were prepared by applying a thin coat of oil to the mould and lining the mould with 1 layer of baking paper, to ensure that the specimen could be demoulded without damage.
3. The concrete was prepared as described in Section 4.6, and the slump test was performed as described in Section 4.7.
4. Each mould was filled in two layers.

   The 100 mm diameter concrete moulds received compaction by rodding each layer with 25 strokes per layer.

   The 105 mm diameter Proctor moulds received compaction by rodding each layer with 20 strokes per layer.
5. It was ensured that the rod did not touch the baseplate in the first layer, and that at least the first 10 strokes of the second layer just penetrated the layer below.

6. The sides of the mould were tapped with a mallet to ensure that holes remaining were closed.
7. As enough concrete had been included in the second layer to overfill the mould, the concrete was then struck off and the surface was smoothed out using a trowel.
8. The moulds were left to cure for 24 hours in a controlled room of temperature 23 °C ± 2 °C.
9. After the initial 24 hour cure, the specimens were demoulded and labelled, and placed into the water bath for 27 days (water bath temperature was 23 °C ± 2 °C). After 28 days of curing in total, the specimens were removed from the curing tank.

Figure 4.11: Concrete specimens after 28 days of curing

4.9 Compressive Strength Test for Concrete

AS 1012.9:2014 Methods of testing concrete

Compressive strength tests— Concrete, mortar and grout specimens

The specimens were removed from the curing tank, and the excess water was wiped from the specimens. The specimen dimensions (average diameter and height) were measured and recorded and the weight was recorded. Specimens were inspected for defects.

1. The specimen was capped with a steel cap with a rubber lining.
2. The platens of the testing machine were cleaned and wiped free of loose particles.
3. The specimen was placed in the machine. The axis of the specimen and the centre of thrust of the platen were aligned, and the upper platen and the capped specimen were brought together.
4. The force was applied without shock at a rate equivalent to 20 MPa compressive stress per minute, until failure. The maximum force applied was recorded.

Figure 4.12: Failure of concrete specimen moulded in normal concrete moulds

Figure 4.13: Failure of concrete specimen moulded in Proctor moulds

5. The compressive strength of the specimen was calculated by dividing the maximum force by the cross-sectional area.

CHAPTER 5 – PRELIMINARY RESULTS

The following chapter will discuss the results that were obtained for the following tests:

- Particle Size Distribution
- Optimal Moisture Content and Maximum Dry Density
- Optimal Road Profile Proportions

5.1 Particle Size Distribution (PSD)

Particle size distribution tests were conducted on each of the six soils, however, 2 soils were disregarded due to the high clay content (resulting in poor workability and inaccurate results for this test). The following graph indicates the three types of gradation that a soil may be classified under; well graded, gap graded and poorly graded. The results for each of the 4 soils, road profile and sand are discussed below.

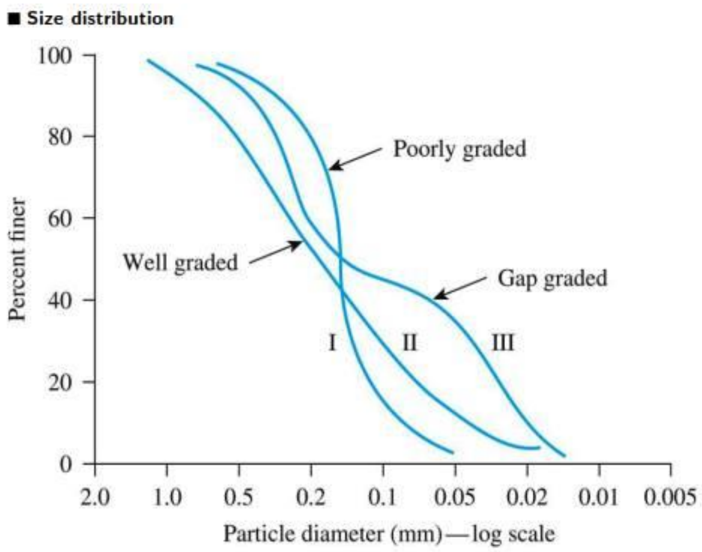

Figure 5.1: Example of Particle Size Distribution Grading Types (Ghabraie, 2014)

5.1.1 Sodosols

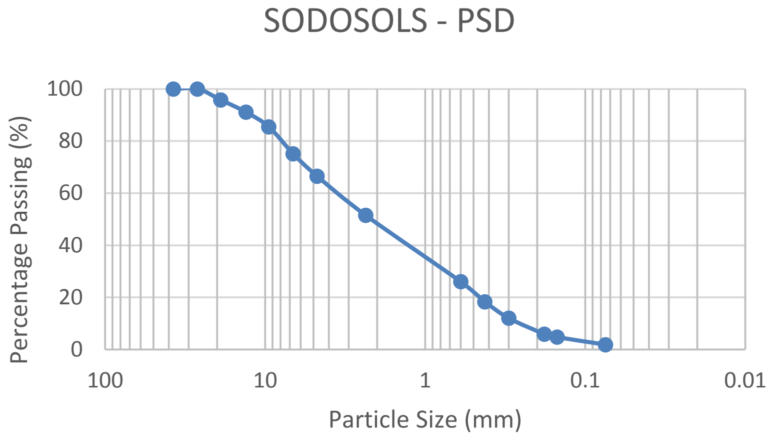

Figure 5.2: Particle Size Distribution curve for Sodosols soil

Sodosols are a sandy clay type of soil, which exhibit greater clay properties as their moisture contents increase. The particle size distribution test indicated that the soil featured particle sizes of 48% gravel and 50% sand. This almost equal distribution identifies Sodosols as a well graded soil.

5.1.2 Chromosols

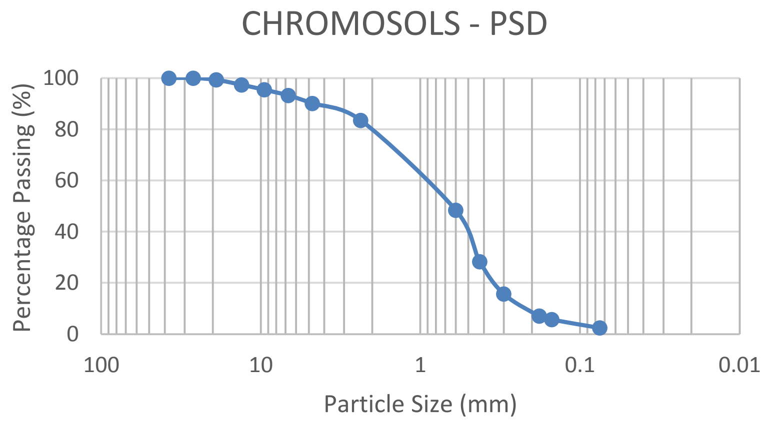

Figure 5.3: Particle Size Distribution curve for Chromosols soil

Chromosols are a sandy type of soil. The particle size distribution test of the sample that was collected indicated that Chromosols are poorly graded, and the analysis indicates that over 80% of the soil was categorised as sand (course, medium and fine).

5.1.3 Dermosols

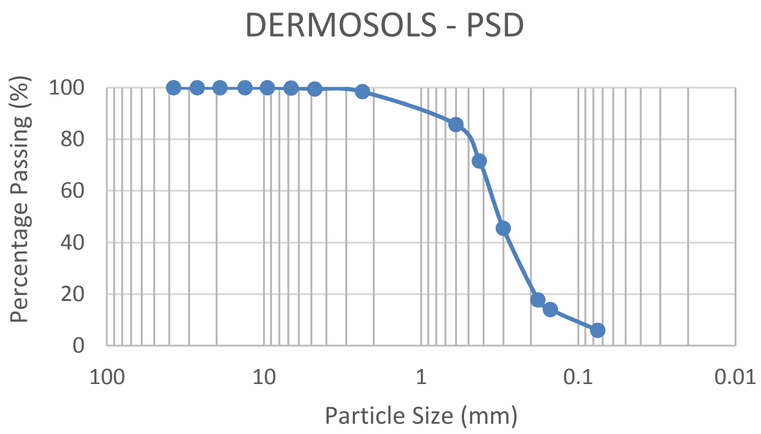

Figure 5.4: Particle Size Distribution curve for Dermosols soil

Dermosols are a sandy and slightly clayey type of soil. The particle size distribution test indicated that Dermosols are poorly graded, and the analysis indicates that over 80% of the soil was categorised as sand (medium and fine) and over 5% as clay. This can be seen in the curve, as the material passed many of the sieves with a 100% passing rate.

5.1.4 Kandosols

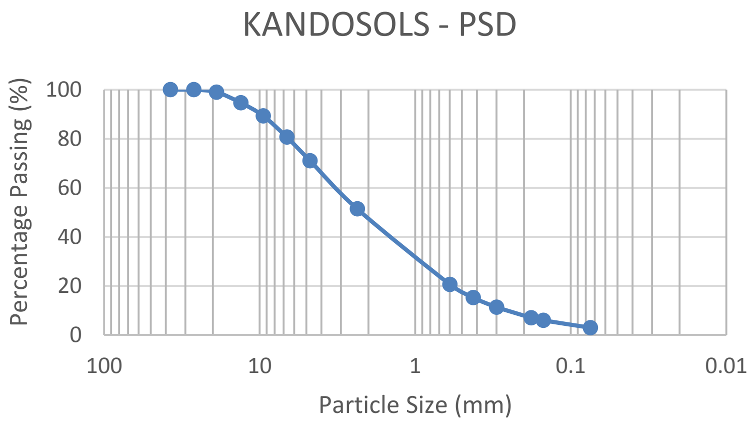

Figure 5.5: Particle Size Distribution curve for Kandosols soil

Kandosols are a gravelly clayey type of soil. The soil is well graded, and the PSD analysis indicates that 49% of the soil was categorised to be the size of gravel and over 48% as the size of sand, providing an equal distribution of large and small particles.

5.1.5 Road Profile

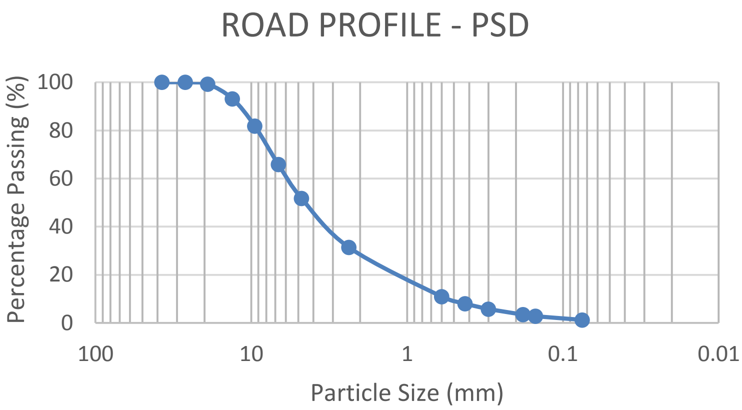

Figure 5.6: Particle Size Distribution curve for Road Profile

Road profile is considered an aggregate rather than a soil. The PSD analysis indicates that road profile is gap graded. This is indeed true, as 69% of the material was classified as gravel and only 30% was classified as sand, as this material consisted of many larger particles and not many fines.

5.1.6 Sand

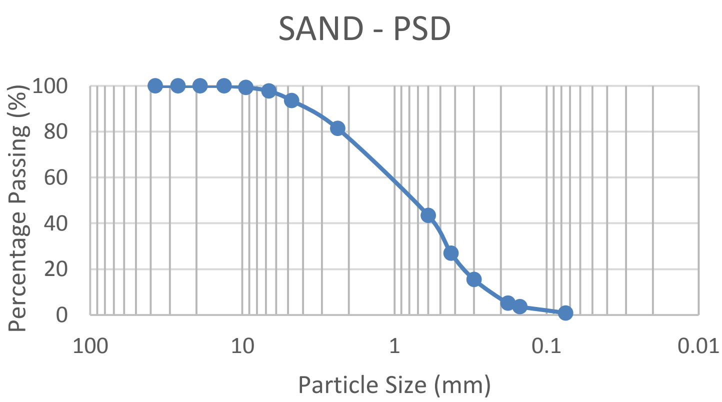

Figure 5.7: Particle Size Distribution curve for Sand (Loam Soil)

The PSD for sand indicates that it is quite poorly graded, as the sand particles are quite fine and passing through most sieves. Over 80% of the material was categorised as sand (course, medium and fine), with only 19% being classed as gravel size.

The table below indicates the percentage of gravel, sand and fines for each material.

Table 5. 1: Percentages of gravel, sand and fines for materials.

	Gravel	Sand	Fines
Sodosols	48%	50%	3%
Chromosols	17%	81%	2%
Dermosols	2%	92%	6%
Kandosols	49%	48%	3%
Sand (loam soil)	19%	80%	1%
Road Profile	69%	30%	1%

The following figure demonstrates that Sodosols and Kandosols were well graded soils, while Chromosols, Dermosols and Sand were poorly graded soils. Road profile was considered to be gap graded. When compared with the table above, it can be seen that Sodosols and Kandosols both feature almost equal percentages of gravel and sand, providing a well graded material. Chromosols, Dermosols and Sand all feature a percentage of sand greater than 80%, and as there is not enough gravel in the material, it is considered poorly graded. Conversely, road profile is considered as gap graded, as there is a much greater percentage of gravel than sand.

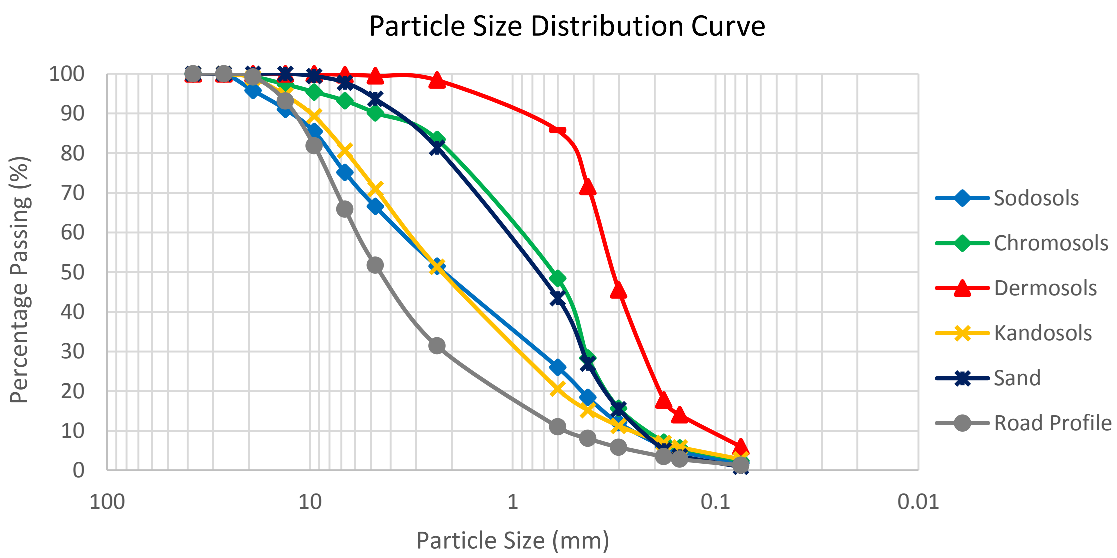

Figure 5.8: Particle Size Distribution Curve for materials used

5.2 Optimal Moisture Content and Maximum Dry Density

The Optimum Moisture Content (OMC) and Maximum Dry Density (MDD) were determined by conducting the Modified Proctor Test, as described in Section 4.1.2. The two clay rich soils (Vertosols and Hydrosols) also underwent this test, but the results proved to be difficult to analyse, and these two soils were omitted due to their difficult workability and seemingly inaccurate results.

The following calculations were undertaken to determine the OMC (w) and MDD (ρ_d).

$$OMC = w\,(\%) = \frac{wet\ soil - dry\ soil}{dry\ soil} \times 100 \qquad \text{Equation 5.1}$$

$$Wet\ Density = \rho = \frac{Mass\ of\ Specimen}{Volume\ of\ Mould} \qquad \text{Equation 5.2}$$

$$MDD = \rho_d = \frac{100 \times \rho}{100 + w} \qquad \text{Equation 5.3}$$

The modified Proctor test was undertaken on each of the four soils, road profile and sand separately, without any mixing of materials, and the results are provided below.

5.2.1 Sodosols

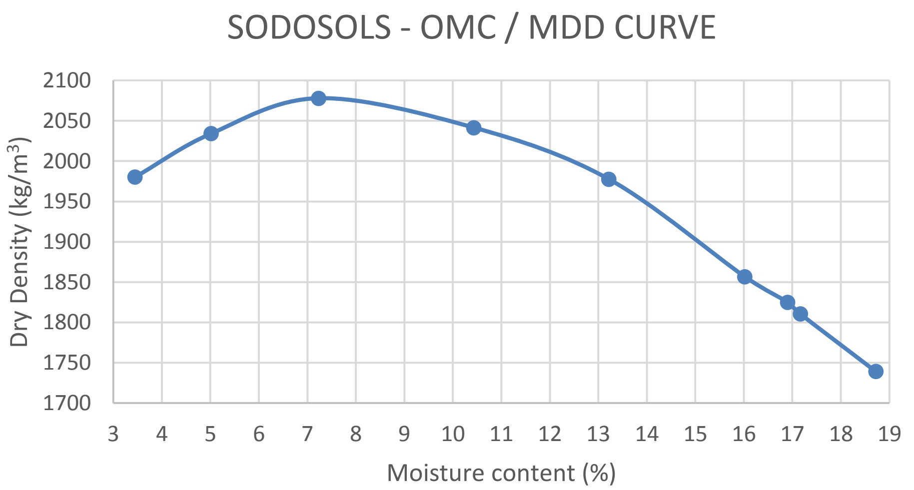

Figure 5.9: OMC / MDD curve for Sodosols soil

This soil required drying in the oven for at least 24 hours, before the samples for the moisture test could be prepared. As the initial moisture of the soil was unknown, the Proctor test was initially conducted without drying, hence the reason for several values much higher than the OMC.

The OMC of this soil is 7.25%, and when compacted at its OMC, the Sodosols sample resulted in a maximum dry density of 2078 kg/m^3. Sodosols were found to have an initial moisture content of 10.5%, and as the OMC is well below this point, this soil required drying before all further testing.

5.2.2 Chromosols

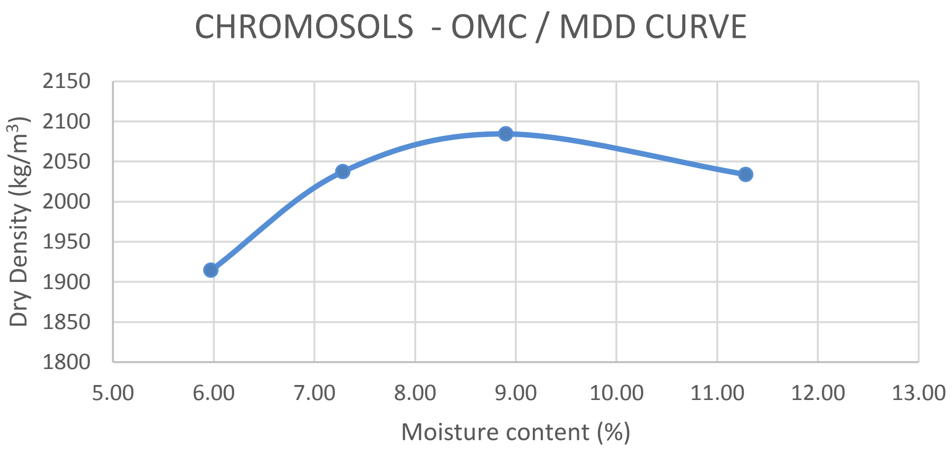

Figure 5.10: OMC / MDD curve for Chromosols soil

Chromosols did not require drying in the oven before testing, as the initial moisture content of the soil was approximately 6%. The OMC of this soil is 8.90% and when compacted at its OMC, the Chromosols sample provided a maximum dry density of 2085 kg/m^3.

5.2.3 Dermosols

This soil did not require drying in the oven before testing, as this soil featured an initial moisture content of approximately 4.8%. The OMC of this soil is approximately 8.75% and when compacted at its OMC, the Dermosols sample reached a maximum dry density of 2106 kg/m^3. The OMC/MDD curve is presented below in Figure 5.11.

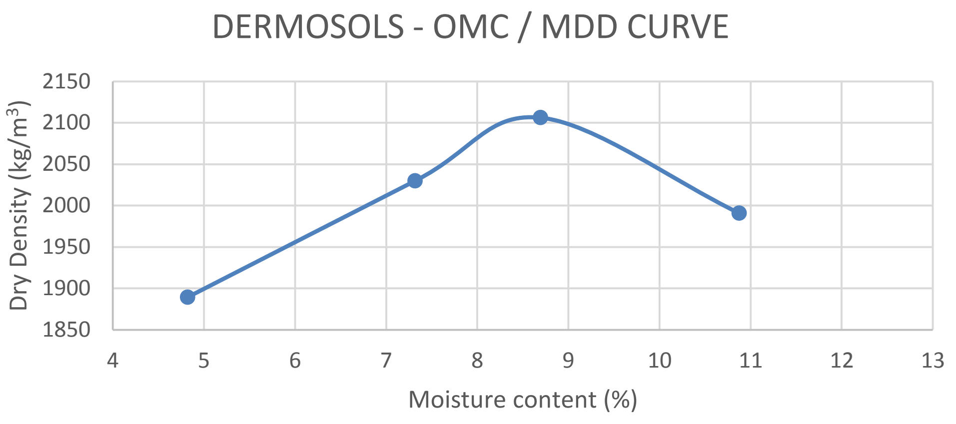

Figure 5.11: OMC / MDD curve for Dermosols soil

5.2.4 Kandosols

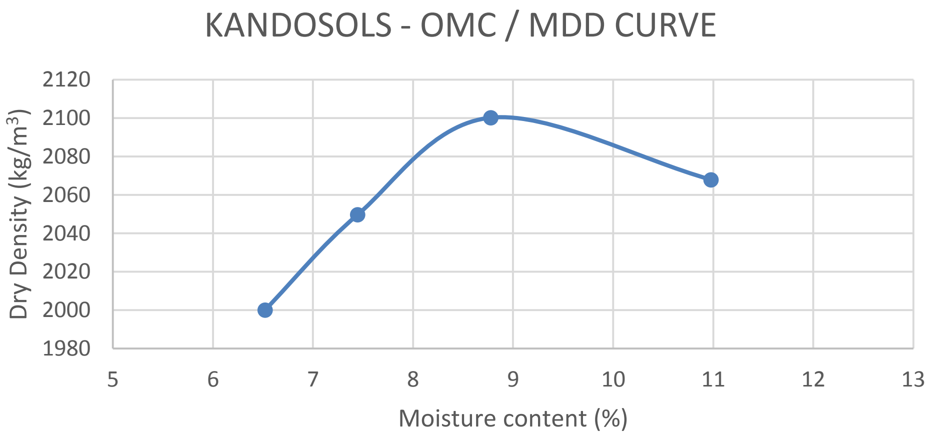

Figure 5.12: OMC / MDD curve for Kandosols soil

Kandosols did not require drying in the oven before testing, as its initial moisture content was 6.5%. The OMC of this soil is approximately 8.80% and when compacted at its OMC, the Kandosols sample reached a maximum dry density of 2100 kg/m^3. Kandosols and Dermosols both did not need extra test samples, as the curves obtained satisfied the requirements set out in the standard.

5.2.5 Road Profile

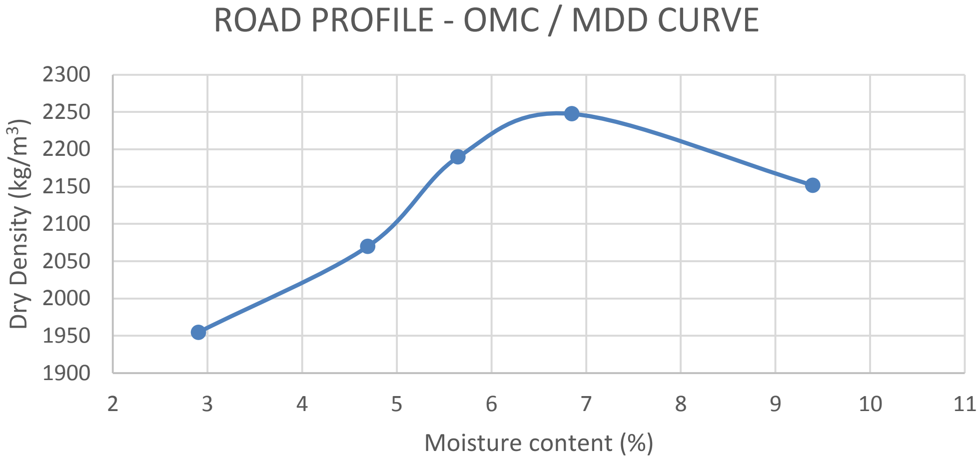

Figure 5.13: OMC / MDD curve for Road Profile

Road profile did not require drying in the oven before testing, as its initial moisture content was quite low (in comparison to the soils) at just under 3%. The OMC of this aggregate material is approximately 6.85% and when compacted at its OMC, the Road Profile sample provided a maximum dry density of 2247 kg/m^3. It can be seen that Road Profile is significantly denser than the four soils and sand.

5.2.6 Sand

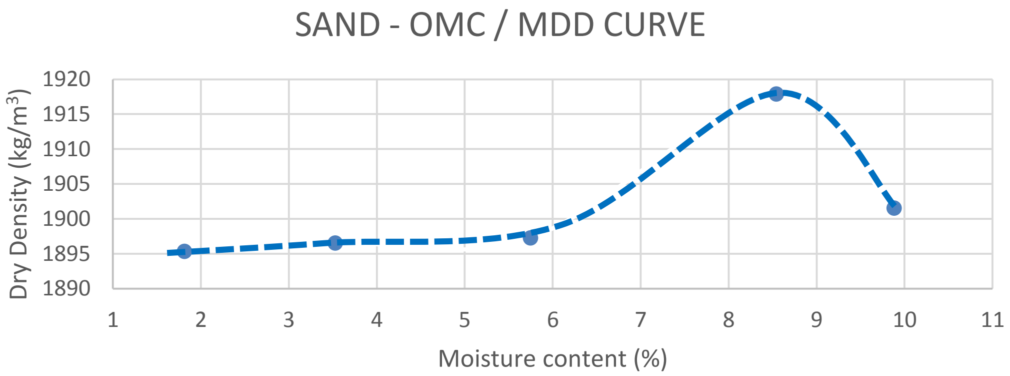

Figure 5.14: OMC / MDD curve for Sand

Sand also did not require drying in the oven before testing, as its initial moisture content was also quite low (in comparison to the soils) at just under 2%. The OMC of the sand is approximately 8.5% and when compacted at its OMC, the sand sample reached a maximum dry density of 1918 kg/m^3. The sand did not behave like the four soils or like the road profile, as there was very little difference in the dry density, though there was significant change in the moisture content. Though there is an improvement to be seen, when the sand was compacted at its OMC, the change is quite little in comparison as the density has only improved by 1.2%, indicating that the sand is not highly reactive to changes in moisture.

The figure below provides an illustrated comparison of the OMC / MDD curve for each material. As can be seen, road profile is the material with the greatest density (as it has the highest curve), while sand has the least density (with the lowest curve). The graph further confirms how flat the moisture curve for sand is, in comparison to other materials. The graph also indicates that the four soils are very similar, and distinguishes the soils from the two other materials. The four soils each feature an optimal density between 2050kg/m^3 and 2150kg/m^3, and optimal moisture contents ranging between 7% and 9%.

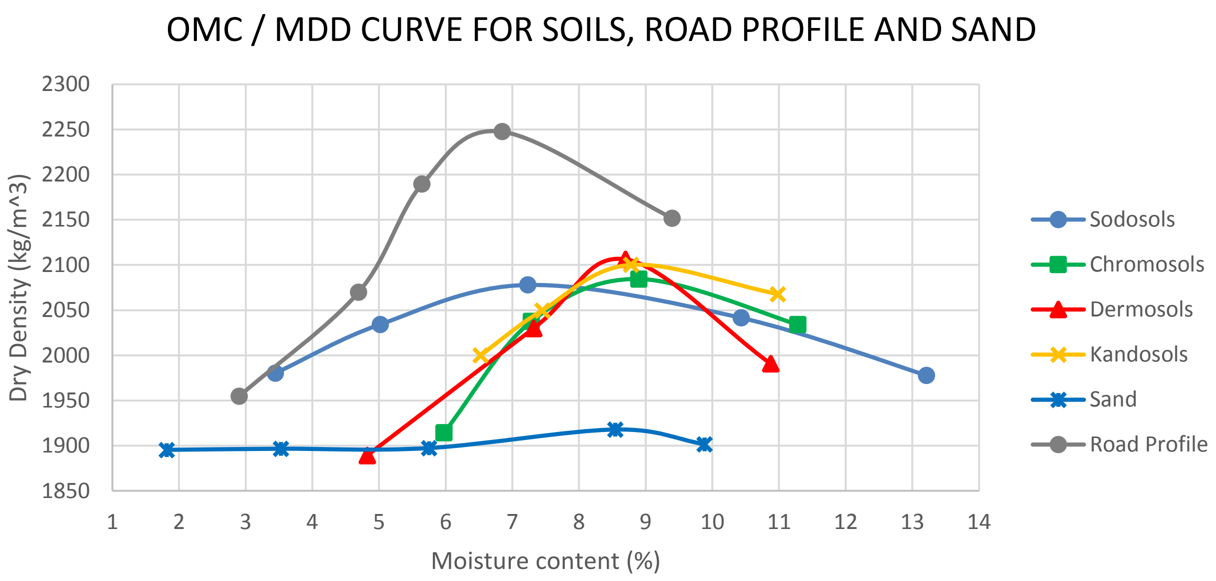

Figure 5.15: OMC / MDD curve for soils, road profile and sand.

None of the soils have particularly narrow curves, indicating that the soils are not highly reactive to changes in moisture contents. Sodosols is the least reactive to changes in moisture levels, as it features the widest curve, while Chromosols and Dermosols are more reactive to changing moisture levels as their curves are narrower in comparison. Road profile is also not highly reactive to changes in moisture content. As stated earlier, the loam soil (sand) is not very reactive to change in moisture content during compaction.

5.3 Optimal Road Profile Proportions

The CBR test was utilised as the best method to determine the optimal road profile percentage for each soil, as no other available test would provide easily comparable results. However, the CBR test required modifications to enable the tests to be conducted for this purpose, with the following reasoning in mind.

- **Unable to soak specimen for 4 days due to time and equipment constraints**
  Due to the extensive amount of testing and limited laboratory bookings, the decision was made that it would not be feasible to undertake all the CBR tests after soaking the specimens for 4 days, as there were 19 specimens that required testing to determine the optimal road profile percentage.
  The laboratory only contained 3 complete sets of CBR equipment (mould, baseplate and surcharges) during this testing phase. If samples were soaked, a minimum of 28 days would have been required to complete this phase of testing, on the condition that access to the laboratory was available every 4 days. As this is not possible (due to weekends and limited lab bookings), the minimum time required if a booking was available every Monday (for compaction and submersion) and Friday (for testing) would have been 7 weeks.
  As further CBR tests were required once the stabilising agent was added, the entire CBR testing phase of this project would have required at least 10 weeks to complete.

- **Health and Safety concerns for personnel, inadequate results and damage to machinery**
  After identifying that soaking each specimen for 4 days was not feasible, the next decision was to compact the specimen as per standard, and conduct the test without the soaking period. This was attempted on four specimens, however; this method was also unacceptable, due to the following reasons.
  Firstly, this method presented to great of a health and safety risk for the testing operator. Compacting 20 specimens with 220 blows per specimen (44 blows per 5 layers), assembling the machinery and conducting the test was a very strenuous and repetitive task that would have resulted in injury.
  Secondly, even if injury was not to occur, it is likely that mistakes would occur during compacting and testing due to fatigue. Furthermore, the results of the specimens that were tested in this manner resulted in CBR values ranging from between 35% and 95%, which did not seem appropriate to compare.
  Finally, conducting the testing on compacted specimens that had not been soaked was very difficult and required at least 20kN to 50kN of force. Not only did this create a

health and safety issue for the testing operator (as the cranking became very rigid and tiring), but also increased the chances of damaging the CBR machine as many specimens were to be tested.

- **Unable to obtain usable values without compaction**

  It was then suggested that the specimen remain uncompacted, however this did not yield usable results. By not compacting the specimen too many voids were present, causing the piston to push through the soil with almost no effort, and providing CBR values that were not usable at all (0.1% or less).

- **Modified Compaction effort**

  Finally, a decision was reached that some compaction effort was required, to minimise the voids present and enable the piston to push against the soil and obtain a reading. The 4.53kg Manual Marshall Compaction hammer was deemed most suitable, as it features a wide and flat face, ensuring that the soil is not disrupted and is more evenly compacted. As the aim of the compaction was to minimise voids, only minimal compaction effort was utilised at a rate of 4 blows per layer, for 3 layers in each specimen.

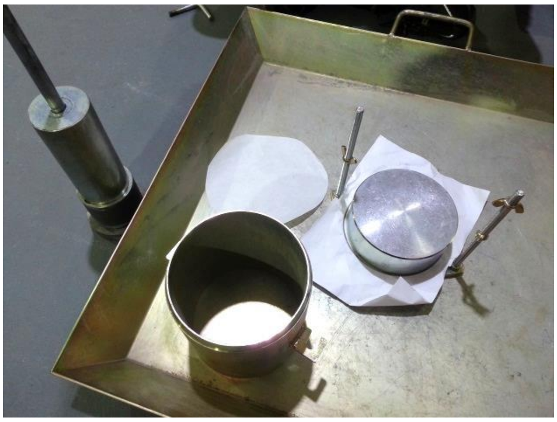

Figure 5.16: Equipment used for modified CBR testing – USQ Lab

This compaction effort resulted in reasonable CBR values (5% to 10%) and the risks of fatigue and injury were greatly reduced. As the results were only being used to determine the optimal road profile percentage, rather than to report the proper CBR values, this method provided the most suitable solution. The differences in the compaction effort and the omission of the soaking period were the main modifications to the CBR standard detailed below.

It is to be noted that the optimal road profile percentage of each soil in soaked conditions may in reality be lesser or greater than what was determined by utilising this method, however; the time, equipment and safety constraints indicate that this is an area of further research and at this current time, beyond the scope of this project. Each soil was tested utilising the following mixtures.

- 100% Soil / 0% Road Profile
- 75% Soil / 25% Road Profile
- 50% Soil / 50% Road Profile
- 25% Soil / 75% Road Profile
- 0% Soil / 100% Road Profile

A summary of the optimal mixtures and their modified CBR values are presented below. CBR values at 2.5mm penetration and 5mm penetration were utilised to plot the graphs presented in this section. By using both penetration points to plot two curves, the relationships can be verified as both curves are similar. This is to reduce the possibility of the curves being affected by a void or the presence of a stone/inconsistency.

Table 5. 2: Optimal road profile proportions

OPTIMAL MIXTURE PROPORTIONS		
SOIL TYPE	**ROAD PROFILE**	**SOIL**
SODOSOLS	25%	75%
CHROMOSOLS	25%	75%
DERMOSOLS	50%	50%
KANDOSOLS	25%	75%

5.3.1 Sodosols

As indicated by the graph below, the Sodosols soil actually benefitted from the inclusion of 25% road profile. When the soil was tested by itself, it resulted in a CBR value of 6.75% (reported as 7%). When a mixture of 75% of Sodosols and 25% road profile was tested, the CBR value increases to its peak of 8.9% (reported as 9%) for this mixture. Further increasing the proportion of road profile resulted in the CBR values to fall, until the lowest CBR value was reached at 5.2% (reported as 5%) for a 100% road profile sample.

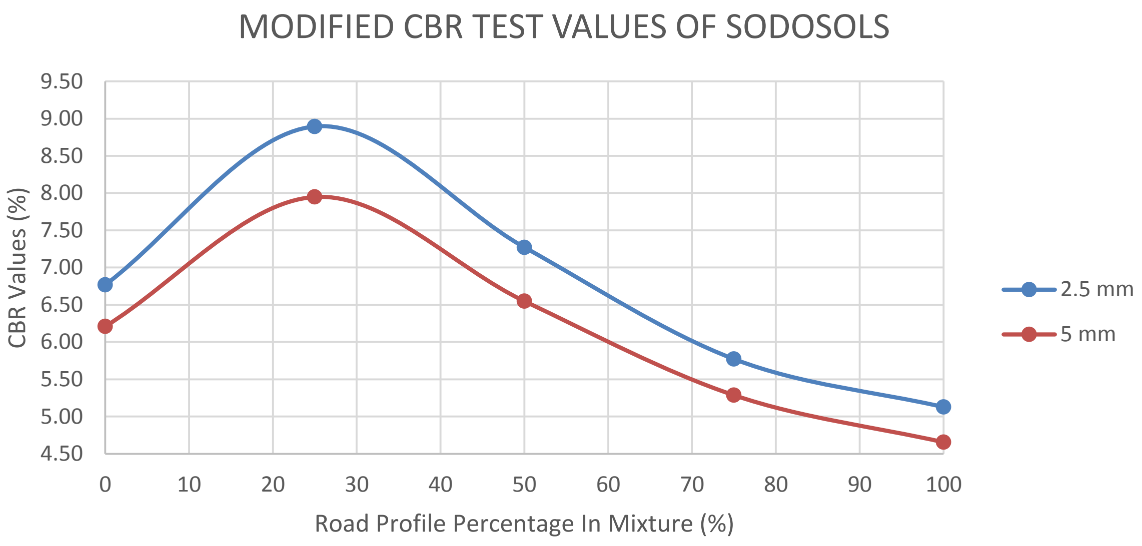

Figure 5.17: Modified CBR Values of Sodosols soil at different road profile proportions

5.3.2 Chromosols

The graph below highlights that Chromosols featured a higher CBR rating naturally, without the addition of any road profile, during this test. As the purpose of this project was to utilise road profile rather than soil just by itself, it was determined that the 75% Chromosols soil / 25% road profile mixture was optimal for this type of soil, which featured a CBR of 5.3% (reported as 5%).

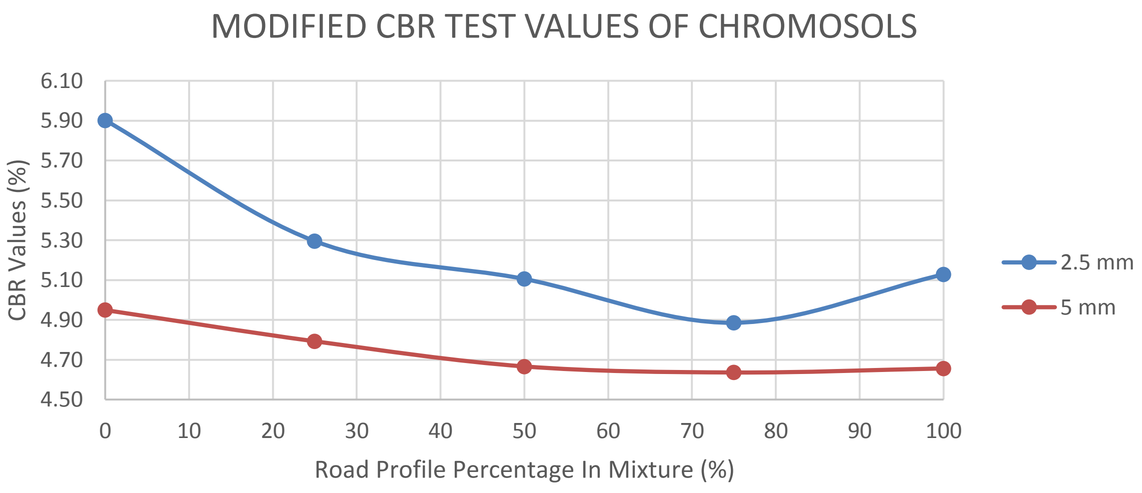

Figure 5.18: Modified CBR Values of Chromosols soil at different road profile proportions

5.3.3 Dermosols

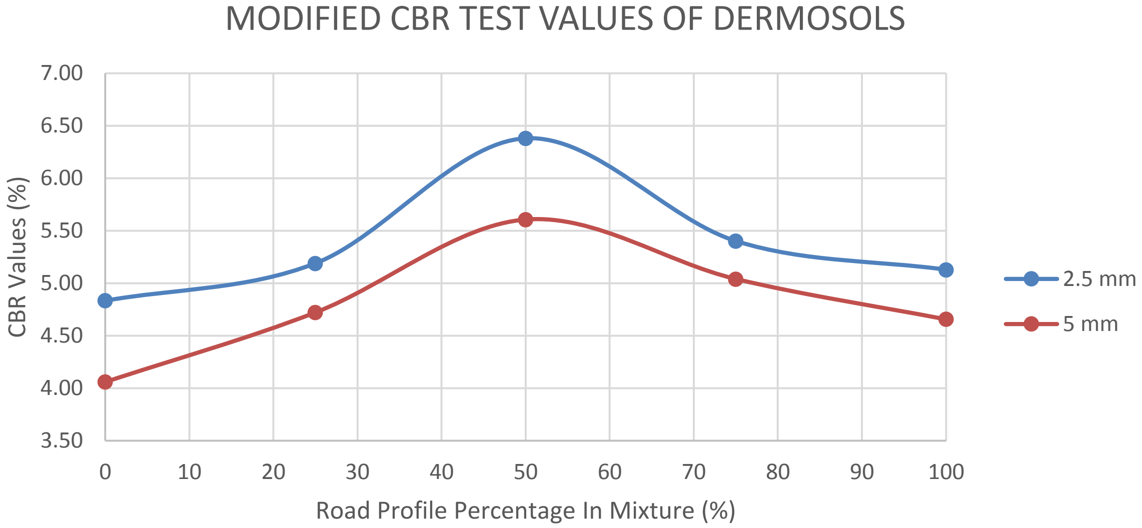

Figure 5.19: Modified CBR Values of Dermosols soil at different road profile proportions

Dermosols performed similar to Sodosols, in terms of the fact that both soils benefitted from the addition of road profile. As indicated by the graph above, the Dermosols soil provides quite a low CBR value when tested by itself, reporting a CBR of only 4%. This type of soil improves to its peak when a mixture of 50% soil / 50% road profile is utilised, resulting in a CBR of 6.4% (reported as 6%). Even a mixture of 25% Dermosols / 75% road profile reports a CBR value of 5%, which is greater than both the soil and the road profile tested by themselves. For the purposes of this project, this soil optimal road profile proportion was taken to be 50% soil / 50% road profile, as per the results given.

5.3.4 Kandosols

The graph below indicates that Kandosols function similarly to Chromosols, in that both soils provide higher CBR values when tested without road profile. As the purpose of this project was to utilise road profile rather than soil just by itself, it was determined that the 75% Kandosols soil / 25% road profile mixture was optimal for this type of soil, which featured a CBR of 5.45% (reported as 5%). Though the values determined at 5mm penetration indicate very little difference, the values at 2.5mm penetration indicate just enough reduction in the CBR values to classify 25% road profile as optimal for this soil, rather than 50% or 75% road profile.

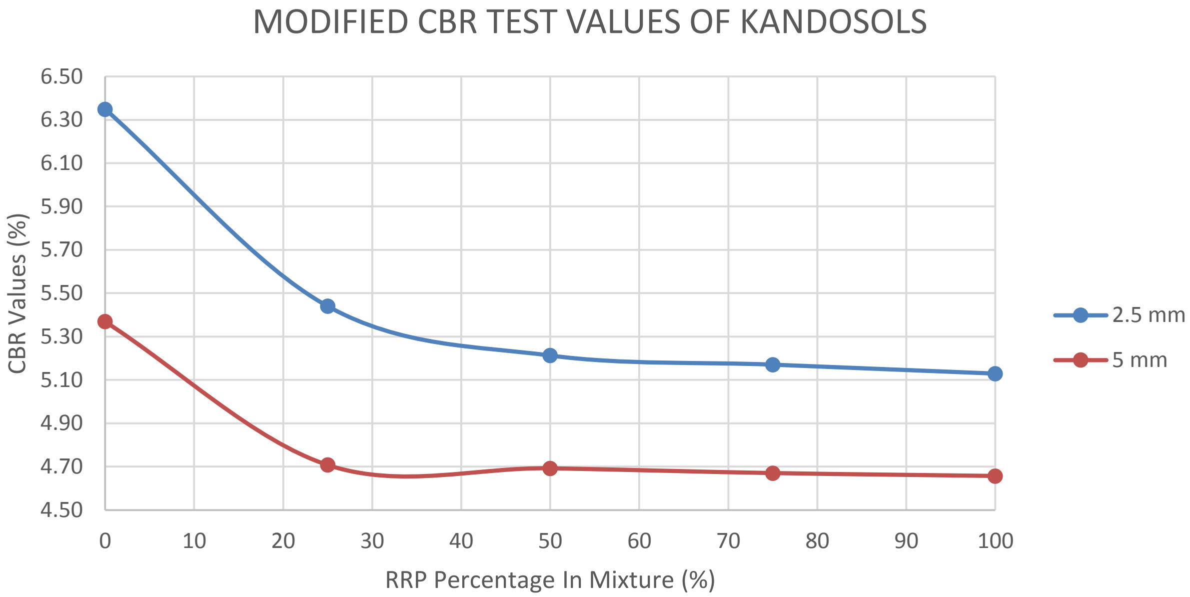

Figure 5.20: Modified CBR Values of Kandosols soil at different road profile proportions

CHAPTER 6 – SIGNIFICANT RESULTS

The following chapter will discuss the results that were obtained for the following tests:

- California Bearing Ratio (CBR)
- Slip resistance
- Unconfined Compressive Strength (compacted soil samples)
- Compressive strength (concrete samples)

6.1 Soaked CBR Tests

After determining the optimal road profile proportions, a full set of soaked CBR tests were conducted for each optimal mix of soil and road profile, with and without PolyCom Stabiliser. Soaked CBR tests were also conducted on Road Profile (RP) and on Sand, also with and without PolyCom, and CBR values were determined using the same CBR calculations, as stated in the previous section. Two simple calculations given in the Australian CBR Standard are utilised to determine the CBR of a specimen, using the force readings at penetrations of 2.5 mm and 5 mm.

$$CBR\ (\%) = \frac{kN_{2.5\,mm}}{13.2} \times 100 \qquad \text{Equation 6.1}$$

$$CBR\ (\%) = \frac{kN_{5.0\,mm}}{19.8} \times 100 \qquad \text{Equation 6.2}$$

The CBR value that is the higher of the two is then reported, as per Australian Standard reporting requirements.

6.1.1 Road Profile

The CBR value of Road Profile (100% road profile without PolyCom) is reported to be 40%. This is close to values reported by Arulrajah et al. (2014), in which the Recycled Asphalt Pavement reported CBR values of 30% – 35%. As can be seen in Figure 6.1 below, the CBR of Road Profile with 0.002% PolyCom added is significantly increased by more than double, to a CBR of 80% - 90%. It is believed that this improvement is due to the road profile material featuring a greater portion of larger particles (69%) allowing the PolyCom Stabiliser to effectively interlock the particles.

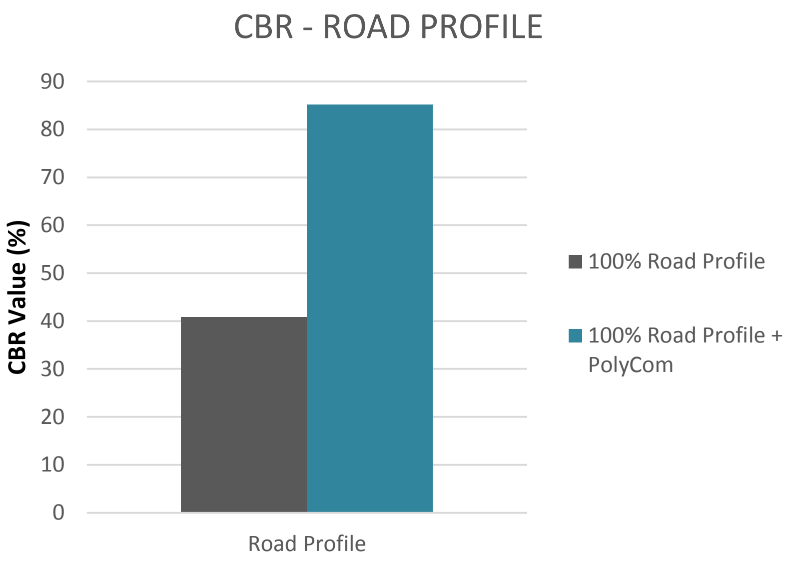

Figure 6.1: CBR Values for Road Profile

6.1.2 Sodosols

The CBR value of the Sodosols soil by itself could not be accurately determined as the soil was very clayey, pushing up the sides of the piston, causing inaccurate unusable readings (even though several attempts were made to identify its CBR). The Sodosols mixture with 25% Road Profile obtained a CBR value of 12%. The low CBR value of the Sodosols soil is due to the clay content of the soil, as CBR Values of clayey soils are estimated to be between 5% and 10% (ARA Inc. ERES Division, 2001).

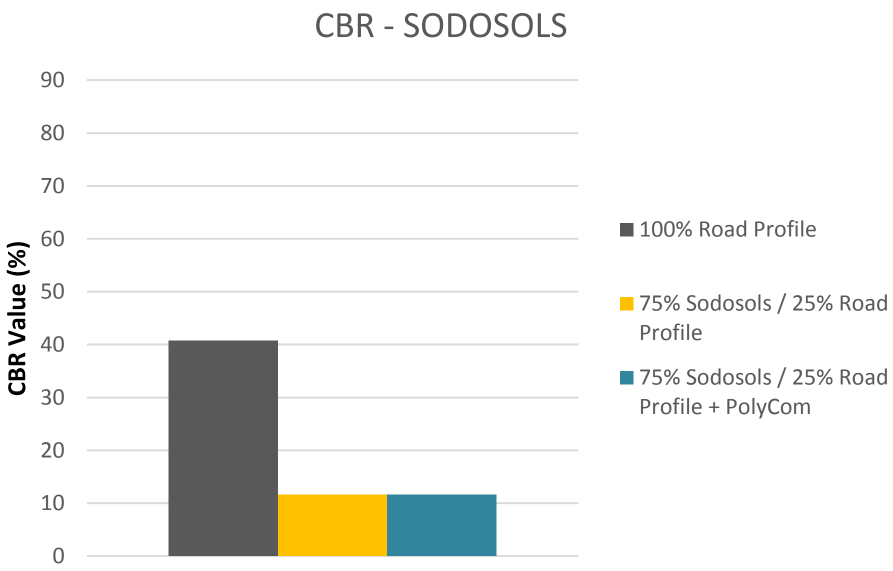

Figure 6.2: CBR Values for Sodosols

The CBR of the Sodosols was not greatly improved as other soils were through the addition of road profile, which is likely due to the clayey behaviour of this soil in soaked conditions. The CBR of the soil and road profile mixture was unfortunately not improved by the addition of PolyCom Stabiliser either, as the mixture with PolyCom reported the same CBR value of 12%, as did the mixture without PolyCom. It may be possible that the clayey behaviour of this soil when wet has impacted the results.

6.1.3 Chromosols

When tested in the soaked CBR test, Chromosols (100% soil) obtained a CBR value of 60%. It can be seen from the graph below, that a significant improvement has been provided by adding 25% road profile to the Chromosols soil, as the CBR value has now risen to 80%. This 33% increase in the CBR rating is believed to be due to this soil providing the stabilisation that the strong aggregates of the road profile requires, resulting in a material that features a higher CBR rating than each material separately.

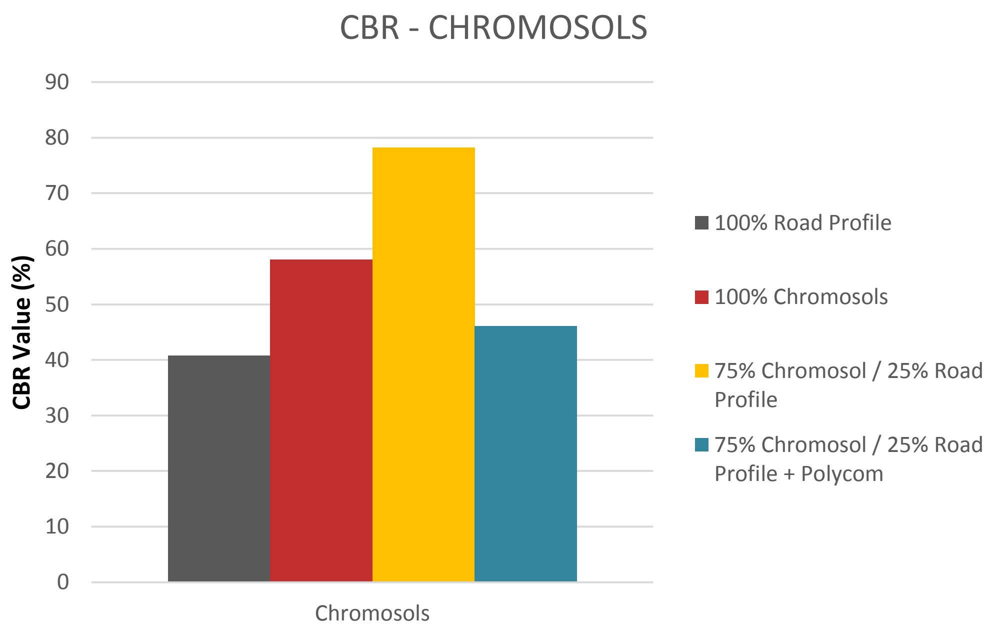

Figure 6.3: CBR Values for Chromosols

With PolyCom Stabiliser in the soil and road profile mixture, the CBR value obtained was only 45%, (a value that is reduced by almost 44% compared to the mixture without PolyCom Stabiliser), which was very unexpected. It is believed that the negative result from the PolyCom Stabiliser is due to the fines in the mixture from the soil, and from the Stabiliser not reacting well to fines when in the moist conditions of the soaked CBR test.

6.1.4 Dermosols

Dermosols (100% soil) yielded a CBR value of 60% when tested in soaked conditions. It can be seen in Figure 6.4 below, that an improvement has been obtained by utilising a 50% road profile / 50% Dermosols mixture, as the CBR value has now risen to 70%, resulting in an increase of 17% in the CBR value. As this soil features a large quantity of fine particles (compared to the other soils tested), the course aggregates of the road profile work well in a 50/50 mixture, allowing this soil to utilise a greater proportion of road profile in its mixture. The course aggregates provide increased strength,
while the fine particles assist in interlocking, binding the particles together, resulting in a material that features a higher CBR rating than each material separately.

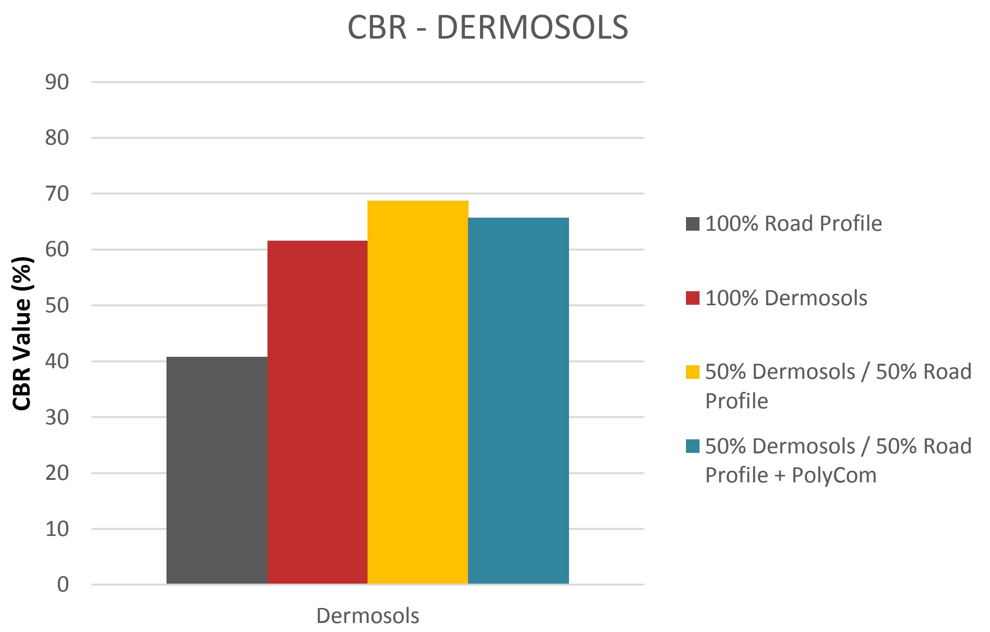

Figure 6.4: CBR Values for Dermosols

The CBR value of the soil and road profile mixture with PolyCom Stabilising Aid was actually lower than the mixture without PolyCom. Once again this reduction in strength was unexpected, however it is to be noticed that the CBR was only reduced by 4%, rather than by a much higher percentage as seen in other soil mixtures (Chromosols and Kandosols). Once again it is believed that the negative result from the PolyCom Stabiliser is due to the fines in the mixture from the soil and the Stabilising not reacting well to fines in moist conditions. It is to be noted that this mixture featured the least reduction in strength when PolyCom was added, and this mixture also features the highest percentage of road profile.

6.1.5 Kandosols

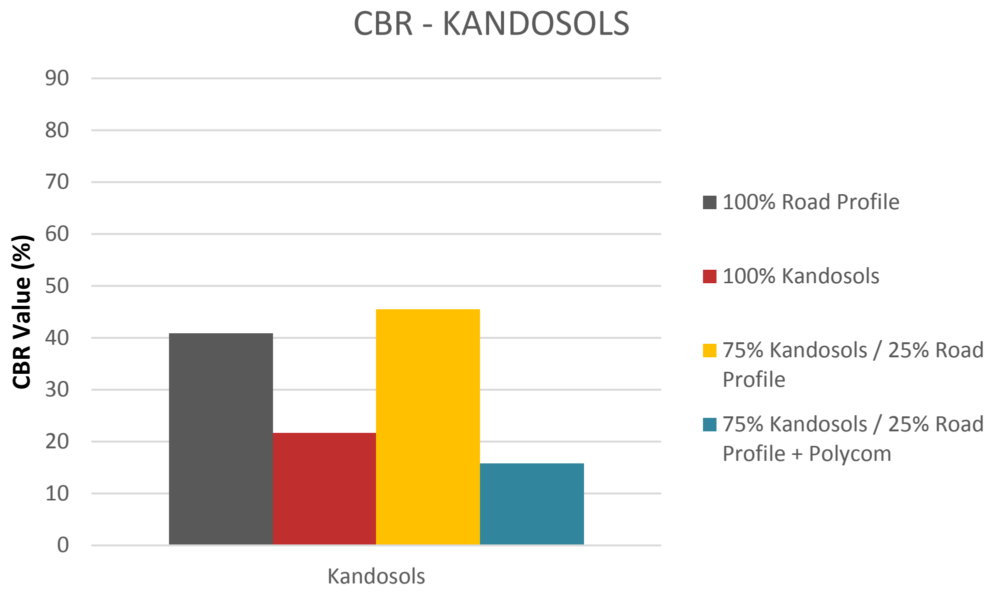

Figure 6.5: CBR Values for Kandosols

Kandosols (100% soil) obtained a CBR value of 20% when soaked. It can be seen from Figure 6.5, that a substantial improvement has been provided by adding 25% road profile to the Kandosols soil, as the CBR value has now risen to 45%. This is an increase of 125% in the CBR rating, which is entirely due to the addition of road profile. The soil and road profile mixture also provided a CBR rating that was higher than both materials separately.

With PolyCom Stabiliser in the soil and road profile mixture, the CBR value obtained was only 16%, (a value that is reduced by 64% compared to the mixture without PolyCom Stabiliser) and is also lower than the CBR value given by the soil itself. Once again, the negative result from the PolyCom Stabiliser is expected to be due to the high fines content, and from the Stabiliser not reacting well to fines when in the moist conditions of the soaked CBR test.

6.1.6 Sand

Sand did not perform very well in the CBR test, in comparison to the other materials tested, and no road profile was added to sand. Though the sand is not very reactive to changing moisture conditions, the sand samples did not compact as densely as soil does. A 100% sand sample without PolyCom provided a CBR value of 18%, performing slightly better than a sample with PolyCom, which only provides a CBR of 17%.

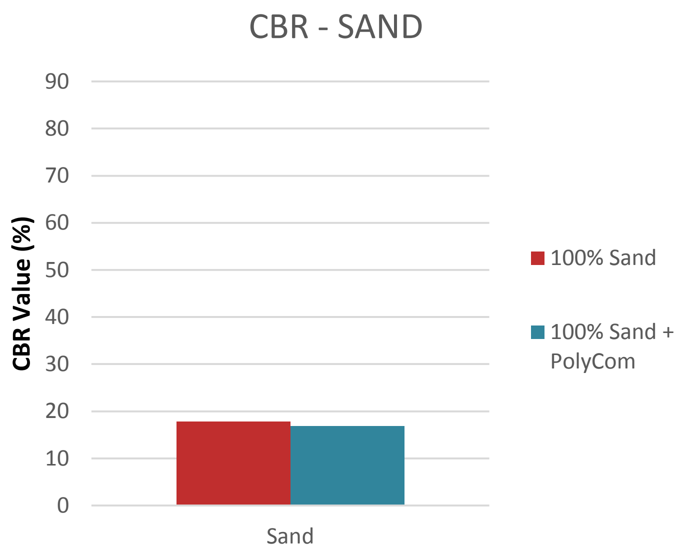

Figure 6.6: CBR Values for Sand (loam soil)

The sand samples were hoped to be utilised as a protective layer on top of the road profile and soil mixtures. Unfortunately, from the results obtained, this would not be feasible or practical. Sand may be a candidate for mixing with road profile, but due to time constraints, this has not yet been tested. It seems likely that PolyCom Stabiliser will not work well with sand even when mixed with road profile.

6.1.7 Overall results of PolyCom Mixtures

Figure 6.7 below presents the CBR results of all the soil mixtures, sand and road profile with and without PolyCom Stabiliser. It was hoped that the PolyCom Stabilising Agent would assist in improving the strength of the mixtures, however that is not the case. The Chromosols and Kandosols mixtures did not benefit at all from the addition of the Stabiliser, and instead their strengths were significantly decreased. The Dermosols mixture and Sand also did not benefit from the Stabilising agent during the soaked CBR tests, as their strengths with PolyCom were slightly lowered, and the Sodosols mixture did not change in strength. The only material to benefit from the addition of PolyCom during the soaked test was Road Profile, which incurred a significant improvement in strength.

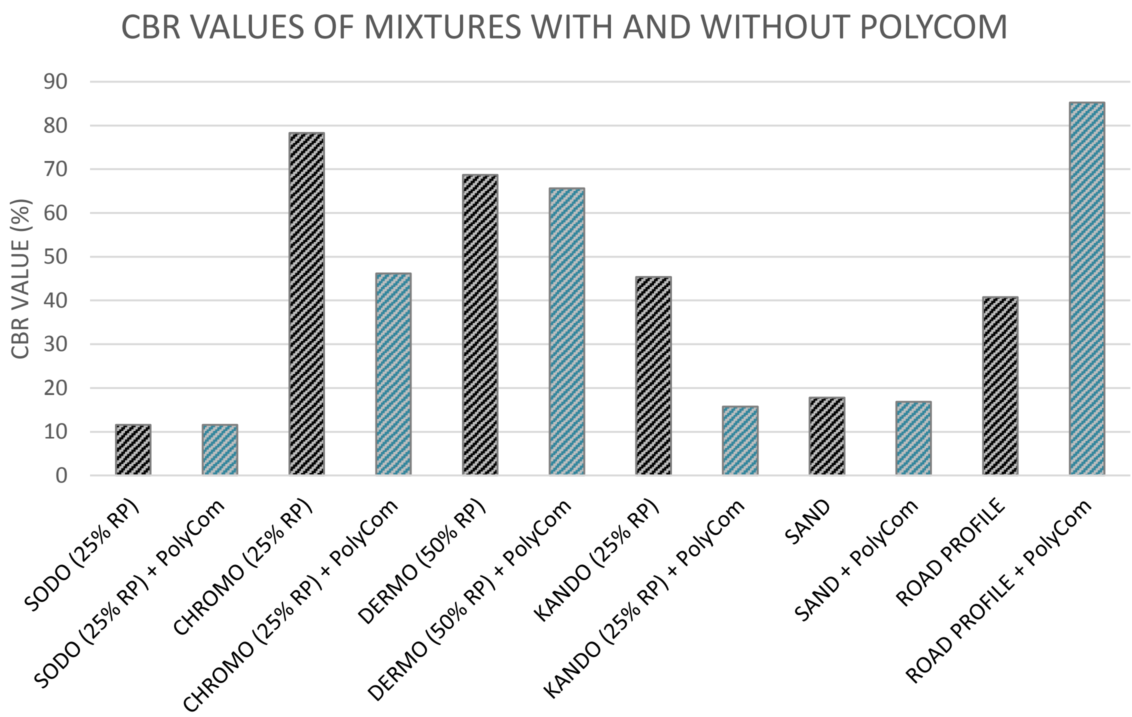

Figure 6.7: CBR Values for soil mixtures, sand and road profile with and without PolyCom

It is difficult to pinpoint the exact cause of the changes in strengths. PolyCom has been found to work well in stabilising soils as well as aggregate materials (Roadmaker, 2014), and has been found to provide benefits such as fines minimisation (Roadmaker, 2014), indicating that it can be used successfully with materials that feature fine particles. A possible cause for the negatively impacted strength values may be that the PolyCom Stabilising Aid does not respond well to increased moisture conditions when used in soils (as would have been the case during the soaking period), instead of aggregates in dry conditions.

PolyCom Stabiliser if often utilised with soil for usage in very dry conditions and with other materials for mining roads, and the stabiliser performs well in these situations. The stabiliser can cause the Optimum Moisture Content of materials to be lowered by 70% at times. It is believed that this is the reason why the Stabiliser does not function well in soaked or moist conditions with materials with fines of approximately 50% or more, as the moisture content of the specimen is much higher than what the Stabiliser is designed for.

6.2 Slip Resistance tests

Slip resistance is an essential aspect of the footpath design process. The Wet Pendulum Slip Resistance test allows for the testing of a pavement material in wet conditions.

Table 2 from AS4586 indicates the different classes, presented as Table 6.1 below. External footpaths must meet a minimum Slip Resistance Value (SRV) requirement for class P4, when tested in wet conditions.

Table 6. 1: Slip Resistance Classes - AS4586 Table 2 (Standards Australia, 2013)

TABLE 2
CLASSIFICATION OF PEDESTRIAN SURFACE MATERIALS ACCORDING TO THE AS 4589 WET PENDULUM TEST

CLASS	Pendulum SRV	
	Slider 96	Slider 55
P5	> 54	> 44
P4	45 – 54	40 – 44
P3	35 – 44	35 – 39
P2	25 – 34	20 – 34
P1	12 – 24	< 20
P0	< 12	

The British Pendulum Number (BPN) is the value provided by each swing, and the SRV is calculated by taking the mean of three consecutive swings. It is assumed that these materials will feature even higher slip resistance values when tested in dry conditions. The following table indicates the average Slip Resistance value and respective class for each material tested.

As can be seen in Table 6.2 below, the SRV of the majority of the road profile and soil mixtures ranged between 56 and 59, with the Sodosols mixture achieving the highest SRV of 67. These mixtures scored values close to brushed concrete, which has a SRV of 70. None of the soil or sand mixtures tested were roughened in any manner, and each material scored a high SRV, enable all materials tested to be classified as Class P5 materials.

Table 6. 2: SRV of all soil/road profile mixtures and sand

MATERIAL	SRV	CLASS
Sodosols + 25% Road Profile	67	P5
Chromosols + 25% Road Profile	58	P5
Dermosols + 50% Road Profile	59	P5
Kandosols + 25% Road Profile	56	P5
Sand (100%)	58	P5
Concrete (against the brush)	70	P5

6.3 Unconfined Compressive Strength (UCS) tests

UCS tests were conducted only on soil and road profile mixtures. Testing was initially performed on samples that were only allowed 3 days to cure (while within the mould), as per PolyCom Stabiliser requirements. After the first samples were tested, it became apparent that the samples were still too damp inside to the point where results were significantly affected. The samples were then allowed an extra 4 days to cure after being demoulded, after 3 days of curing in the mould (7 days total curing). A slight problem was still present as many of the specimens would break during the demoulding process.

To overcome this problem, it was then decided that the samples would be demoulded immediately after compaction while they were still at maximum moisture levels, and allowed to cure for 7 days in air. Though this may not have been in line with PolyCom requirements, this method of demoulding was the only method that yielded a full set of unbroken, usable specimens (2 specimens per mixture). This change in methods may have affected the strength of the specimens, as the specimens that were allowed to cure for 3 days in the mould and 4 days in air, did achieve slightly higher results (approximately 1 MPa greater). The Unconfined Compressive Strength of soil is given by the following calculation:

$$UCS = \frac{F \times \left(\frac{\pi}{4} \times 1000\right)}{D_{Average}}$$ Equation 6.3

Where:

F = Load at failure (kN)

$D_{Average}$ = Average diameter (mm).

Cracking of the specimens occurred irregularly, with cracking from top to bottom in a diagonal fashion. Some specimens seemed to exhibit cracking similar to cone and shear cracking while other seemed to be closer to columnar cracking (*refer to Section 6.4 for overview on cracking types)*. None of the specimens featured just these types of cracking however, so none of the specimens could be classed into any of the typical concrete cracking types.

Figure 6.8: Sodosols specimen after UCS test.

Figure 6.9: Chromosols specimen after UCS test.

The following results are the compressive strengths for each specimen along with the properties of the specimens. These results are from specimens that were immediately demoulded and allowed to cure for 7 days. As can be seen in Table 6.3 below, the compressive strengths are quite low, averaging approximately 2 MPa for the soil and road profile mixtures.

Table 6. 3: Compressive strength of soil/road profile specimens tested (7 day air cure)

Specimen Description	Diameter (mm)	Height (mm)	Mass (g)	Load at Failure (kN)	Compressive Strength (MPa)	Average Compressive Strength (MPa)
SAMPLE 1 SODO/25% RP	104.4	116	2094.7	21.3 kN	2.49 MPa	2.37 MPa
SAMPLE 2 SODO/25% RP	105.0	116	2085.0	19.5 kN	2.25 MPa	
SAMPLE 3 CHROMO/25% RP	104.4	117	2139.2	14.6 kN	1.71 MPa	1.82 MPa
SAMPLE 4 CHROMO/25% RP	104.6	117	2125.7	16.5 kN	1.93 MPa	
SAMPLE 5 DERMO/50% RP	105.0	116	2171.7	16.9 kN	1.95 MPa	1.95 MPa
SAMPLE 6 DERMO/25% RP	104.8	116	2094.7	16.8 kN	1.95 MPa	
SAMPLE 7 KANDO/25% RP	104.8	117	2180.8	17.4 kN	2.02 MPa	2.03 MPa
SAMPLE 8 KANDO/25% RP	104.4	117	2168.6	17.4 kN	2.04 MPa	

Given above are the average compressive strengths of each of the mixtures. As required per standard, at least 2 specimens of each sample must be utilised to determine the compressive strength. It is apparent that the soil and road profile mixtures will require improvement before they are able to match the strength of the 20 MPa concrete currently for pedestrian footpaths.

Though these results are low in comparison to concrete, they are quite comparable to results obtained by others. Arulrajah, Horpibulsuk & Hoy (2016) identified that a Recycled Asphalt Pavement and Fly Ash Mixture could obtain a strength of 2.5 MPa, which is quite close to what was achieved. Arulrajah et al. (2014) indicated that Recycled Asphalt Pavement by itself only achieves a strength of approximately 0.1 MPa. In contrast to this, the addition of soil to road profile does provide a significant improvement, and though only low strength of approximately 2 MPa was achieved across the mixtures, this is comparable to other recycled materials.

Regardless, there is much potential for the materials to be utilised in their current state, as Ipswich City Council considers many other aspects such as costs, slip resistance and environmental impact alongside strength. Factors such as environmental impact and cost are especially a problem when providing thoroughfare for national parks and rural areas, and the soil and road profile mixtures may perform much better in these aspects than concrete, as the materials are of minimal cost and are 100% recycled.

6.4 Compressive strength tests (concrete samples)

The compressive strength test results are presented in Table 6.4 and Table 6.5, along with the properties of the specimens tested. The concrete specimens were utilised as control specimens, to ensure that the compressive strength machine was working correctly, and as a measure of comparison.

No specimens featured major defects, such as cracking, before the test. Specimens No.'s 2 – 11 featured a slight unevenness on the surface that was to be capped with the steel cap, but no major defects. Specimen No. 12 featured a more uneven surface, as the surface that was to be capped was quite rippled. The bottom surface of all specimens (that was placed against the machine without any capping) was smooth on all specimens. Note that Specimen No. 1 was utilised to calibrate the machine, and its results have been disregarded.

Table 6. 4: Properties of concrete specimens 2 - 9 (Concrete Moulds)

SPECIMEN (No.)	Diameter (mm)	Height (mm)	Mass (g)	Load at Failure (kN)	Compressive Strength (MPa)
2	100.0	200	3448.2	136.9 kN	17.43 MPa
3	99.6	198	3428.3	145.5 kN	18.68 MPa
4	99.8	198	3428.2	147.7 kN	18.88 MPa
5	99.8	198	3464.8	143.0 kN	18.29 MPa
6	99.6	199	3433.1	146.4 kN	18.79 MPa
7	99.8	198	3432.9	151.0 kN	19.30 MPa
8	99.8	198	3437.4	148.9 kN	19.03 MPa
9	100.8	198	3501.8	148.6 kN	18.62 MPa

Table 6. 5: Properties of concrete specimens 10 – 12 (Proctor Moulds)

SPECIMEN (No.)	Diameter (mm)	Height (mm)	Mass (g)	Load at Failure (kN)	Compressive Strength (MPa)
10	104.8	114	2173.4	169.0 kN	19.59 MPa
11	104.8	115	2178.6	174.1 kN	20.19 MPa
12	104.6	115	2169.2	189.6 kN	22.06 MPa

Figure 6.10 below indicates common failure types. Specimens No. 2 – 9 all experienced a diagonal shear failure. Diagonal shear failure generally arises when proper alignment may have not occurred, and the load is concentrated on one side of the cylinder (American Concrete Institute, 2016). In these cases, the cylinder will fail prematurely, which is likely the reason why the cylinder did not obtain strengths closer to 25 MPa. This may have been contributed to by the capped surface being slightly uneven, as none of the specimens were levelled with a grinder after curing.

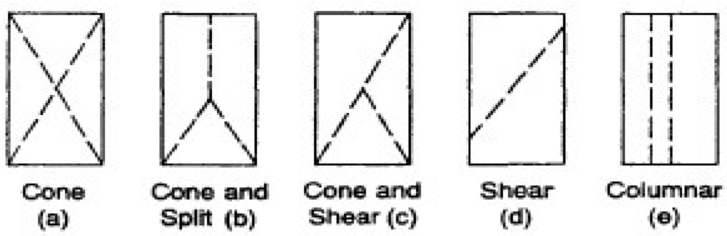

Figure 6.10: Concrete Specimen Failure Types (American Concrete Institute 2016)

Figure 6.11: Concrete specimen faillure (normal mould) after compressive test.

Figure 6.12: Concrete specimen failure (Proctor mould) after compressive test.

Concrete samples moulded in the Proctor moulds (105 mm diameter, 115 mm height) (Specimen No 10 - 12) experienced irregular failure patterns. These irregular failure patterns may have been contributed to by the capped surface being slightly uneven, as specimens were not levelled with a grinder. Specimen No. 12 featured an especially rippled, uneven surface. Furthermore, the rubber seal on the steel cap did not fit properly on the specimens, as the Proctor specimens were 5 mm greater in diameter, than what the rubber seal on the steel cap was designed for.

The average strength of the concrete specimens moulded in the normal concrete moulds was 18.63 MPa. The average strength of the concrete specimens moulded in the Proctor moulds was 20.61 MPa. None of the specimens reached the strength of 25 MPa, though they were prepared using N25 concrete. As discussed above, this could have been due to unevenness in the surface, causing the load to be distributed more to one side, rather than evenly, during the compression test, causing premature failure. As the soil/road profile samples were prepared in the Proctor moulds, it is more appropriate to compare soil/road profile mixtures with the concrete samples prepared in the Proctor mould. Nonetheless, the concrete samples achieved much greater strengths than what the soil/road profile mixtures did, as they only averaged strengths of 1.82 MPa – 2.37 MPa.

It is important to consider however, that the soil/road profile samples are 99.998% recycled material. The concrete utilised by Ipswich Council, as well as the concrete utilised during testing, does not feature recycled aggregates. The use of recycled aggregates instead of natural aggregates causes the strength of concrete to decrease. Abhiram, Manoj & Saravanakumar (2016) report that a 25% decrease in strength was recorded when natural aggregates were replaced by recycled aggregates for concrete. Their study indicates that concrete that features a compressive strength of 25 MPa when using natural (unused) aggregates falls to 18.75 MPa when recycled aggregate are used.

Another study conducted by Albaladejo et al. (2016) indicates that the usage of 75% recycled aggregates in concrete, lowers the strength by at least 35%. Their studies utilised (natural aggregate) concrete that achieved a compressive strength of 20 MPa. When the aggregates utilised for the concrete were replaced with 75% recycled aggregates, the strength of the concrete fell to 13 MPa. While the soil/road profile mixtures may have only achieved a strength of approximately 2 MPa, they are made from 99.998% recycled materials (if not 100% with the exclusion of PolyCom). As the components of concrete (cement, aggregates, etc.) are replaced with recycled materials, the strength of the concrete is also reduced.

7.0 CONCLUSIONS AND RECOMMENDATIONS

7.1 Research Conclusions

Sustainable pavement materials are an important issue in modern day construction. Utilising road profile material for pedestrian thoroughfare is a possible low cost, feasible and recycled material option for the near future. While there are many options to utilise road profile with virgin materials (such as Portland Cement), mixing new resources with road profile defeats the purpose of recycling and sustainability. Thus, to develop a 100% recycled material, natural soils within the region can be utilised with road profile, providing a sustainable, low cost and environmentally friendly alternative to concrete.

Road profile was successfully mixed with four soils common to the Ipswich region. Sodosols, Chromosols and Kandosols performed well in mixtures of 25% road profile and 75% soil. Dermosols featured the highest sand and fines contents from all the soils, enabling the Dermosols soil to utilise a mixture of 50% road profile and 50% soil. Further soaked CBR testing may also indicate that the soils are able to utilise greater proportions of road profile than 25% and 50%. Laboratory testing of four soil and road profile mixtures yielded successful results for CBR, Slip Resistance and UCS testing. Extra testing objectives such as direct or triaxial shear and erosion testing could not be completed due to time and equipment constraints; however, all the required objectives that were envisioned for this project were achieved.

CBR testing of the four different mixtures yielded generally positive results. Chromosols, Dermosols and Kandosols mixtures with road profile achieved CBR values of 80%, 70% and 45% respectively. This CBR value was higher than each of the soils or road profile when independently tested. When the mixtures were tested with PolyCom Stabiliser included, the CBR values were actually lowered. Though this was unfortunate and unexpected, this indicates that the soil and road profile mixtures can be utilised for field testing without a stabiliser, classing the road profile and soil material as 100% recycled. The mixtures provided compressive strengths of 1.82 MPa to 2.37 MPa and each mixture achieved the highest slip resistance class rating (P5 rating) enabling it to meet the slip resistance requirements for an outdoor footpath material.

Each of the four soils featured promising results, especially Chromosols, Dermosols and Kandosols. While the overall strength of the mixtures is low, it is important to note that there are many aspects that Councils consider alongside strength, including cost, recyclability, sustainability and slip resistance. The soil and road profile mixtures performed well in these areas, thus the material may still be suitable for footpaths, especially in rural areas and national parks.

7.2 Recommendations for Further Work

There are several areas of testing that can be undertaken to further this project. Road profile and soil do provide promising results, and the material is made from 100% recycled materials, providing a sustainable and environmentally considerate option.

This project required a lot of time as the properties and reactions of the soil were unknown, and a lot of preliminary work was required to determine the properties of the soils (such as Optimum Moisture Content and Maximum Dry Density). Furthermore, many constraints were experienced due to time and equipment limitations, as CBR tests require at least 5 days to conduct (4 days for soaking and 1 day for compaction and testing) and only limited equipment and testing time are available.

Areas that this project can further investigate are:

- Conducting soaked CBR testing to identify the optimal road profile percentage under soaked conditions.
- Conducting CBR and UCS testing on mixtures with higher percentages of road profile than optimal, to identify how much road profile can be utilised while still yielding adequate results.
- Conducting shear tests such as direct shear or triaxial shear.
- Conducting erosion testing to identify the weaknesses or strengths of the material when exposed to different water flows.
- Changing the Stabilising Agent to suit the material better (note: PolyCom Stabiliser may provide better results with higher proportions of aggregate).
- Conducting a cost-benefit analysis on the optimal materials.
- Developing the material for other purposes, such as fill, subgrade for roads and temporary thoroughfare.

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APPENDIX A – PROJECT SPECIFICATION

For:

Scott Ervin Jackson.

Title:

Development of a sustainable footpath material utilising recycled road profile, natural soils and PolyCom Stabilising Aid.

Major:

Civil Engineering

Supervisors:

Buddhi Wahalathantri

Yan Zhuge

Sponsorship:

Ipswich City Council

SEALS Group Pty Ltd

Enrolment:

- ENG4111, EXT - S1, 2016
- ENG4112, EXT - S2, 2016

Project Aim:

To develop a sustainable and inexpensive material for footpaths utilising recycled road profile, naturally occurring soils around Ipswich and PolyCom Stabilising Aid.

Programme: Issue E, 20th March 2016

- Conduct research regarding footpath materials, pavement standards, soils within the region, erosion, recycled road profile characteristics and PolyCom Stabilisation properties.
- Liaise with Ipswich City Council and SEALS Group, Supervisors and Lab technicians to arrange materials, permits, meetings, access to resources and equipment and testing.
- Conduct testing such as California Bearing Ratio Test, Standard Compaction Test, Compressive Strength Test and Slip Resistance.

- Analyse results and characteristics relating to strength, slip resistance and compaction rates.
- Compare and evaluate results between non-PolyCom mixtures and PolyCom mixtures.
- Compare and evaluate results between PolyCom mixtures and N-25 concrete samples.
- Identify optimal mixtures of recycled road profile for different soils from laboratory testing.

If time and resources permit:

- Conduct density testing of the soils, using the sand cone test.
- Conduct triaxial shear testing.
- Propose recommendations for improvement where necessary.

APPENDIX B – RISK ASSESSMENT

As this project required extensive laboratory testing, the following risk assessments were conducted.

- Particle size distribution test
- Modified Proctor Compaction test
- CBR soil tests (with and without PolyCom and Recycled Road Profile)
- Compressive Strength testing (on concrete and on soil with PolyCom and Recycled Road Profile)

Safety in the laboratory is top priority to ensuring that the project is conducted safely and completed on time. To minimise risks and ensure safety at all times, all personal protective equipment required was worn at all times (steel capped safety boots, gloves, masks, gloves, etc.). All personnel involved in testing were properly briefed and aware of each type of test conducted. Furthermore, it was ensured that all personnel had read the correct Australian standards to ensure that the testing was performed correctly and accurately. The below risk matrix enables the correct classification of the risks involved, and its components are explained in the following tables.

Risk Matrix					
Probability	**Consequence**				
	Insignificant No Injury 0-$5K	Minor First Aid $5K-$50K	Moderate Med Treatment $50K-$100K	Major Serious Injury $100K-$250K	Catastrophic Death More than $250K
Almost Certain 1 in 2	M	H	E	E	E
Likely 1 in 100	M	H	H	E	E
Possible 1 in 1,000	L	M	H	H	H
Unlikely 1 in 10,000	L	L	M	M	M
Rare 1 in 1,000,000	L	L	L	L	L
Recommended Action Guide					
Extreme:	E= Extreme Risk – Task *MUST NOT* proceed				
High:	H = High Risk – Special Procedures Required (Contact USQSafe) Approval by VC only				
Medium:	M= Medium Risk - A Risk Management Plan/Safe Work Method Statement is required				
Low:	L= Low Risk - Manage by routine procedures.				

USQ RISK RATING ADAPTED FROM AS436:2004

Note: In estimating the level of risk, initially estimate the risk with existing controls and then review risk controls if risk level arising from the risks is not minimal

Table 1 - Consequence

Level	Descriptor	Examples of Description
1	Insignificant	No injuries. Minor delays. Little financial loss. $0 - $4,999*
2	Minor	First aid required. Small spill/gas release easily contained within work area. Nil environmental impact. Financial loss $5,000 - $49,999*
3	Moderate	Medical treatment required. Large spill/gas release contained on campus with help of emergency services. Nil environmental impact. Financial loss $50,000 - $99,999*
4	Major	Extensive or multiple injuries. Hospitalisation required. Permanent severe health effects. Spill/gas release spreads outside campus area. Minimal environmental impact. Financial loss $100,000 - $250,000*
5	Catastrophic	Death of one or more people. Toxic substance or toxic gas release spreads outside campus area. Release of genetically modified organism (s) (GMO). Major environmental impact. Financial loss greater than $250,000*

Table 2 - Probability

Level	Descriptor	Examples of Description
A	Almost certain	The event is expected to occur in most circumstances. Common or repetitive occurrence at USQ. Constant exposure to hazard. Very high probability of damage.
B	Likely	The event will probably occur in most circumstances. Known history of occurrence at USQ. Frequent exposure to hazard. High probability of damage.
C	Possible	The event could occur at some time. History of single occurrence at USQ. Regular or occasional exposure to hazard. Moderate probability of damage.

D	Unlikely	The event is not likely to occur. Known occurrence in industry. Infrequent exposure to hazard. Low probability of damage.
E	Rare	The event may occur only in exceptional circumstances. No reported occurrence globally. Rare exposure to hazard. Very low probability of damage. Requires multiple system failures.

Recommended Action Guide:

Abbrev	Action Level	Descriptor
E	Extreme	The proposed task or process activity MUST NOT proceed until the supervisor has reviewed the task or process design and risk controls. They must take steps to firstly eliminate the risk and if this is not possible to introduce measures to control the risk by reducing the level of risk to the lowest level achievable. In the case of an existing hazard that is identified, controls must be put in place immediately.
H	High	Urgent action is required to eliminate or reduce the foreseeable risk arising from the task or process. The supervisor must be made aware of the hazard. However, the supervisor may give special permission for staff to undertake some high risk activities provided that system of work is clearly documented, specific training has been given in the required procedure and an adequate review of the task and risk controls has been undertaken. This includes providing risk controls identified in Legislation, Australian Standards, Codes of Practice etc.* A detailed Standard Operating Procedure is required. * and monitoring of its implementation must occur to check the risk level
M	Moderate	Action to eliminate or reduce the risk is required within a specified period. The supervisor should approve all moderate risk task or process activities. A Standard Operating Procedure or Safe Work Method statement is required
L	Low	Manage by routine procedures.

*Note: These regulatory documents identify specific requirements/controls that must be implemented to reduce the risk of an individual undertaking the task to a level that the regulatory body identifies as being acceptable.

B1: Particle Size Distribution Test

UNIVERSITY OF SOUTHERN QUEENSLAND

University of Southern Queensland Print View

USQ Safety Risk Management System

Safety Risk Management Plan

Risk Management Plan ID:	Status:	Current User:	Author:	Supervisor:	Approver:
RMP_2016_299	*Approve*	i:0#.w|usq\u1043993	i:0#.w|usq\u1043993	i:0#.w|usq\zhuge	i:0#.w|usq\zhuge

Assessment Title:	Development of a sustainable footpath material utilising recycled road profile, natural soils and PolyCom Stabilising Aid.	Assessment Date:	8/04/2016
Workplace (Division/Faculty/Section):	Faculty of Health, Engineering and Sciences	Review Date: (5 years maximum)	

Context

DESCRIPTION:

What is the task/event/purchase/project/procedure?	Particle Size Distribution Test		
Why is it being conducted?	Research project		
Where is it being conducted?	Springfield engineering laboratories		
Course code (if applicable)	ENG4111 and ENG4112	Chemical Name (if applicable)	

WHAT ARE THE NOMINAL CONDITIONS?

Personnel involved	Scott Jackson
Equipment	Scales, Sieves and Mechanical Sieve Shaker
Environment	Engineering laboratories
Other	
Briefly explain the procedure/process	As per AS 1289.5.2.1-2003, Wetting soil samples with water and using the modified rammer to compact soils into moulds with 25 blows for 5 layers. Moulds will be placed into the CBR load frame, and once the mould is in place the crank needs to be turned until maximum penetration at a certain speed. Once complete the pressure can be released.

Assessment Team - who is conducting the assessment?

Assessor(s):	Krystal Kumar (0061047892)
Others consulted: (eg elected health and safety representative, other personnel exposed to risks)	

Risk Register and Analysis

	Step 1	Step 2	Step 2a	Step 3				Step 4				
	Hazards: From step 1 or more if identified	*The Risk:* What can happen if exposed to the hazard with existing controls in place?	*Existing Controls:* What are the existing controls that are already in place?	*Risk Assessment:* Consequence x Probability = Risk Level				*Additional Controls:* Enter additional controls if required to reduce the risk level	*Risk assessment with additional controls:* Has the consequence or probability changed?			
				Consequence	*Probability*	*Risk Level*	*ALARP*		*Consequence*	*Probability*	*Risk Level*	*ALARP*
	Example											
	Working in temperatures over 35° C	*Heat stress/heat stroke/exhaustion leading to serious personal injury/death*	*Regular breaks, chilled water available, loose clothing, fatigue management policy.*	*catastrophic*	*possible*	*high*	*No*	*temporary shade shelters, essential tasks only, close supervision, buddy system*	*catastrophic*	*unlikely*	*mod*	*Yes*
1	Soil handling	Inhalation of fine particles, and/or skin and eye irritation.	Adequate ventilation, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves). Limiting access of persons to the area during activity, being aware of medical resources (first aid kits, emergency phone numbers) and good housekeeping.	Insignifica	Rare	Low	☑					☐
2	Physical injury ...	Injury to self (back and/or neck)	Proper lifting techniques, maximum solo lifting limit 20kg. Limiting access of persons to the area during activity and being aware of medical resources (first aid kits, emergency phone numbers). Regular breaks, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves) being aware of the surroundings and good housekeeping.	Insignifica	Possible	Low	☑					☐

Risk Register and Analysis

	Step 1	Step 2	Step 2a	Step 3				Step 4				
	Hazards: From step 1 or more if identified	*The Risk:* What can happen if exposed to the hazard with existing controls in place?	*Existing Controls:* What are the existing controls that are already in place?	*Risk Assessment:* Consequence x Probability = Risk Level				*Additional Controls:* Enter additional controls if required to reduce the risk level	*Risk assessment with additional controls:* Has the consequence or probability changed?			
				Consequence	*Probability*	*Risk Level*	*ALARP*		*Consequence*	*Probability*	*Risk Level*	*ALARP*
	Example											
	Working in temperatures over 35° C	*Heat stress/heat stroke/exhaustion leading to serious personal injury/death*	*Regular breaks, chilled water available, loose clothing, fatigue management policy.*	*catastrophic*	*possible*	*high*	*No*	*temporary shade shelters, essential tasks only, close supervision, buddy system*	*catastrophic*	*unlikely*	*mod*	*Yes*
1	Soil handling	Inhalation of fine particles, and/or skin and eye irritation.	Adequate ventilation, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves). Limiting access of persons to the area during activity, being aware of medical resources (first aid kits, emergency phone numbers) and good housekeeping.	Insignifica	Rare	Low	☑					☐
2	Physical injury ...	Injury to self (back and/or neck)	Proper lifting techniques, maximum solo lifting limit 20kg. Limiting access of persons to the area during activity and being aware of medical resources (first aid kits, emergency phone numbers). Regular breaks, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves) being aware of the surroundings and good housekeeping.	Insignifica	Possible	Low	☑					☐

Step 5 - Action Plan (for controls not already in place)

	Additional Controls:	*Exclude from Action Plan: (repeated control)*	*Resources:*	*Persons Responsible:*	*Proposed Implementation Date:*

Supporting Attachments

No file attached

Step 6 – Request Approval

Drafters Name: *Scott jackson* *Draft Date:* *8/04/2016*

Drafters Comments:

Assessment Approval: All risks are marked as ALARP

Maximum Residual Risk Level: Low - Manager/Supervisor Approval Required

Approver: *Yan Zhuge*

Supervisor: (optional - for notification of Risk Assessment only) *Yan Zhuge*

Document Status: *Approve*

Step 6 – Approval

Approvers Name: *Yan Zhuge* *Approvers Position Title:* *A/Prof*

Approvers Comments: *All activities are low risk and standard lab testing*

I am satisfied that the risks are as low as reasonably practicable and that the resources required will be provided.

Approval Decision: Approve

Approve / Reject Date: *18/04/2016*

Document Status: *Approve*

B2: Proctor Compaction test

UNIVERSITY OF SOUTHERN QUEENSLAND

University of Southern Queensland Print View

USQ Safety Risk Management System

Safety Risk Management Plan

Risk Management Plan ID:	Status:	Current User:	Author:	Supervisor:	Approver:
RMP_2016_296	*Approve*	i:0#.w|usq\u1043993	i:0#.w|usq\u1043993	i:0#.w|usq\zhuge	i:0#.w|usq\zhuge

Assessment Title:	Development of a sustainable footpath material utilising recycled road profile, natural soils and PolyCom Stabilising Aid.	Assessment Date:	8/04/2016
Workplace (Division/Faculty/Section):	Faculty of Health, Engineering and Sciences	Review Date:	25/04/2016 (5 years maximum)

Context

DESCRIPTION:

What is the task/event/purchase/project/procedure?	Proctor compaction test
Why is it being conducted?	Research project
Where is it being conducted?	Springfield engineering laboratories
Course code (if applicable)	ENG4111 and ENG4112
Chemical Name (if applicable)	

WHAT ARE THE NOMINAL CONDITIONS?

Personnel involved	Scott Jackson
Equipment	Rammer, Moulds, Scales and Oven
Environment	Engineering laboratories
Other	
Briefly explain the procedure/process	As per AS 1289.5.2.1-2003, Wetting soil samples with water and using the modified rammer to compact soils into moulds with 25 blows for 5 layers. Samples will need to be dried in the oven before being weighed on scales.

Assessment Team - who is conducting the assessment?

Assessor(s):	Krystal Kumar (0061047892)
Others consulted: (eg elected health and safety representative, other personnel exposed to risks)	

Risk Register and Analysis

	Step 1	Step 2	Step 2a	Step 3				Step 4				
	Hazards: From step 1 or more if identified	*The Risk:* What can happen if exposed to the hazard with existing controls in place?	*Existing Controls:* What are the existing controls that are already in place?	*Risk Assessment:* Consequence x Probability = Risk Level				*Additional Controls:* Enter additional controls if required to reduce the risk level	*Risk assessment with additional controls:* Has the consequence or probability changed?			
				Consequence	*Probability*	*Risk Level*	*ALARP*		*Consequence*	*Probability*	*Risk Level*	*ALARP*
	Example											
	Working in temperatures over 35°C	*Heat stress/heat stroke/exhaustion leading to serious personal injury/death*	*Regular breaks, chilled water available, loose clothing, fatigue management policy.*	*catastrophic*	*possible*	*high*	*No*	*temporary shade shelters, essential tasks only, close supervision, buddy system*	*catastrophic*	*unlikely*	*mod*	*Yes*
1	Soil handling	Inhalation of fine particles, and/or skin and eye irritation.	Adequate ventilation, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves). Limiting access of persons to the area during activity, being aware of medical resources (first aid kits, emergency phone numbers) and good housekeeping.	Insignifica	Rare	Low	✓					☐
2	Physical injury ...	Injury to self (back and/or neck)	Proper lifting techniques, maximum solo lifting limit 20kg. Limiting access of persons to the area during activity and being aware of medical resources (first aid kits, emergency phone numbers). Regular breaks, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves) being aware of the surroundings and good housekeeping.	Insignifica	Possible	Low	✓					☐

3	Compaction sta...	Hearing loss, pinching of limbs and personal injury.	Wearing ear plugs, opening doors to allow sound to travel outside and taking regular breaks. Awareness of pinch points, people and surroundings and taking regular breaks. Limiting access of persons to the area during the activity, being aware of medical resources (first aid kits, emergency phone numbers) and good housekeeping.	Insignifica	Possible	Low	✓					☐
4	Using a oven to...	Burns from hot items or hot materials	Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves) and good housekeeping. Being aware of medical resources (first aid kits, emergency phone numbers) and good housekeeping.	Insignifica	Rare	Low	✓					☐

Step 5 - Action Plan (for controls not already in place)

	Additional Controls:	*Exclude from Action Plan: (repeated control)*	*Resources:*	*Persons Responsible:*	*Proposed Implementation Date:*

Supporting Attachments

No file attached

Step 6 – Request Approval

Drafters Name:	Scott Jackson	*Draft Date:*	8/04/2016
Drafters Comments:			

Assessment Approval: All risks are marked as ALARP

Maximum Residual Risk Level: Low - Manager/Supervisor Approval Required

Approver: *Yan Zhuge*	*Supervisor: (optional - for notification of Risk Assessment only)* *Yan Zhuge*	*Document Status:*	Approve

B3: CBR Testing of soil without PolyCom

University of Southern Queensland Print View

UNIVERSITY OF SOUTHERN QUEENSLAND

USQ Safety Risk Management System

Safety Risk Management Plan

Risk Management Plan ID:	Status:	Current User:	Author:	Supervisor:	Approver:
RMP_2016_297	*Approve*	i:0#.w|usq\u1043993	i:0#.w|usq\u1043993	i:0#.w|usq\zhuge	i:0#.w|usq\zhuge

Assessment Title:	Development of a sustainable footpath material utilising recycled road profile, natural soils and PolyCom Stabilising Aid.	Assessment Date:	8/04/2016
Workplace (Division/Faculty/Section):	Faculty of Health, Engineering and Sciences	Review Date:	(5 years maximum)

Context

DESCRIPTION:

What is the task/event/purchase/project/procedure?	Measuring CBR values of soil
Why is it being conducted?	Research project
Where is it being conducted?	Springfield engineering laboratories
Course code (if applicable)	ENG4111 and ENG4112
Chemical Name (if applicable)	

WHAT ARE THE NOMINAL CONDITIONS?

Personnel involved	Scott Jackson
Equipment	Rammer, Moulds, Scales and CBR load frame
Environment	Engineering laboratories
Other	
Briefly explain the procedure/process	As per AS 1289.5.2.1-2003, Wetting soil samples with water and using the modified rammer to compact soils into moulds with 25 blows for 5 layers. Moulds will be placed into the CBR load frame, and once the mould is in place the crank needs to be turned until maximum penetration at a certain speed. Once complete the pressure can be released.

Assessment Team - who is conducting the assessment?

Assessor(s):	Krystal Kumar (0061047892)
Others consulted: (eg elected health and safety representative, other personnel exposed to risks)	

Risk Register and Analysis

	Step 1	Step 2	Step 2a	Step 3				Step 4				
	Hazards: From step 1 or more if identified	*The Risk:* What can happen if exposed to the hazard with existing controls in place?	*Existing Controls:* What are the existing controls that are already in place?	*Risk Assessment:* Consequence x Probability = Risk Level				*Additional Controls:* Enter additional controls if required to reduce the risk level	*Risk assessment with additional controls:* Has the consequence or probability changed?			
				Consequence	*Probability*	*Risk Level*	*ALARP*		*Consequence*	*Probability*	*Risk Level*	*ALARP*
	Example											
	Working in temperatures over 35° C	*Heat stress/heat stroke/exhaustion leading to serious personal injury/death*	*Regular breaks, chilled water available, loose clothing, fatigue management policy.*	*catastrophic*	*possible*	*high*	*No*	*temporary shade shelters, essential tasks only, close supervision, buddy system*	*catastrophic*	*unlikely*	*mod*	*Yes*
1	Soil handling	Inhalation of fine particles, and/or skin and eye irritation.	Adequate ventilation, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves). Limiting access of persons to the area during activity, being aware of medical resources (first aid kits, emergency phone numbers) and good housekeeping.	Insignifica	Rare	Low	✓					
2	Mixing of Recy...	Personal injury.	Wearing ear plugs, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves), taking regular breaks and good housekeeping.	Insignifica	Rare	Low	✓					

3	Physical injury ...	Injury to self (back and/or neck)	Proper lifting techniques, maximum solo lifting limit 20kg. Limiting access of persons to the area during activity and being aware of medical resources (first aid kits, emergency phone numbers). Regular breaks, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves) being aware of the surroundings and good housekeeping.	Insignifica	Possible	Low	☑					☐
4	Compaction sta..	Hearing loss, pinching of limbs and personal injury.	Wearing ear plugs, opening doors to allow sound to travel outside and taking regular breaks. Awareness of pinch points, people and surroundings and taking regular breaks. Limiting access of persons to the area during the activity, being aware of medical resources (first aid kits, emergency phone numbers) and good housekeeping.	Insignifica	Possible	Low	☑					☐
5	Using CBR Load...	Crushing of limbs from machinery	Proper usage of machinery, awareness of: pinch points, people and surroundings. Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves). Having a spotter in case something is to happen. Limiting access of persons to the area during activity, being aware of medical resources (first aid kits, emergency phone numbers) and good housekeeping.	Moderate	Unlikely	Mediu...	☐	Limit amount of work per day to reduce repetitive stress injuries, having a spotter encase something is to happen.	Moderate	Rare	Low	☑

Step 5 - Action Plan (for controls not already in place)

	Additional Controls:	*Exclude from Action Plan: (repeated control)*	*Resources:*	*Persons Responsible:*	*Proposed Implementation Date:*
5	Limit amount of work per day to reduce repetitive stress injuries, having a spotter encase something is to happen.	☐			

Supporting Attachments

No file attached

Step 6 – Request Approval

Drafters Name: *Scott jackson*

Draft Date: *8/04/2016*

Drafters Comments:

Assessment Approval: All risks are marked as ALARP

Maximum Residual Risk Level: Low - Manager/Supervisor Approval Required

Approver: *Yan Zhuge*

Supervisor: (optional - for notification of Risk Assessment only) *Yan Zhuge*

Document Status: *Approve*

Step 6 – Approval

Approvers Name: *Yan Zhuge*

Approvers Position Title: *A/Prof*

Approvers Comments: *All activities are low risk and standard lab testing*

I am satisfied that the risks are as low as reasonably practicable and that the resources required will be provided.

Approval Decision: Approve

Approve / Reject Date: *18/04/2016*

Document Status: *Approve*

B4: CBR Testing of soil with PolyCom and Recycled Road Profile

University of Southern Queensland | Print View

USQ Safety Risk Management System

Safety Risk Management Plan

Risk Management Plan ID:	Status:	Current User:	Author:	Supervisor:	Approver:
RMP_2016_298	*Approve*	i:0#.w|usq\u1043993	i:0#.w|usq\u1043993	i:0#.w|usq\zhuge	i:0#.w|usq\zhuge

Assessment Title:	Development of a sustainable footpath material utilising recycled road profile, natural soils and PolyCom Stabilising Aid.	Assessment Date:	8/04/2016
Workplace (Division/Faculty/Section):	Faculty of Health, Engineering and Sciences	Review Date:	25/04/2016 (5 years maximum)

Context

DESCRIPTION:

What is the task/event/purchase/project/procedure?	Measuring CBR values of soil with PolyCom and Recycled road profile
Why is it being conducted?	Research project
Where is it being conducted?	Springfield engineering laboratories
Course code (if applicable)	ENG4111 and ENG4112
Chemical Name (if applicable)	

WHAT ARE THE NOMINAL CONDITIONS?

Personnel involved	Scott Jackson
Equipment	Rammer, Moulds, Scales and CBR load frame
Environment	Engineering laboratories
Other	
Briefly explain the procedure/process	Mixing the soils with the right amount of Recycled road profile and PolyCom so that the sample can be compacted. As per AS 1289.5.2.1-2003, Wetting soil samples with water and using the modified rammer to compact soils into moulds with 25 blows for 5 layers for the CBR test. Moulds will be placed into the CBR load frame, and once the mould is in place the crank needs to be turned until maximum penetration at a certain speed. Once complete the pressure can be released.

Assessment Team - who is conducting the assessment?

Assessor(s):	Krystal Kumar (0061047892)
Others consulted: (eg elected health and safety representative, other personnel exposed to risks)	

Risk Register and Analysis

	Step 1	Step 2	Step 2a	Step 3				Step 4				
	Hazards: From step 1 or more if identified	*The Risk:* What can happen if exposed to the hazard with existing controls in place?	*Existing Controls:* What are the existing controls that are already in place?	*Risk Assessment:* Consequence x Probability = Risk Level				*Additional Controls:* Enter additional controls if required to reduce the risk level	*Risk assessment with additional controls:* Has the consequence or probability changed?			
				Consequence	*Probability*	*Risk Level*	*ALARP*		*Consequence*	*Probability*	*Risk Level*	*ALARP*
	Example											
	Working in temperatures over 35° C	*Heat stress/heat stroke/exhaustion leading to serious personal injury/death*	*Regular breaks, chilled water available, loose clothing, fatigue management policy.*	*catastrophic*	*possible*	*high*	*No*	*temporary shade shelters, essential tasks only, close supervision, buddy system*	*catastrophic*	*unlikely*	*mod*	*Yes*
1	Soil handling	Inhalation of fine particles, and/or skin and eye irritation.	Adequate ventilation, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves). Limiting access of persons to the area during activity, being aware of medical resources (first aid kits, emergency phone numbers) and good housekeeping.	Insignifica	Rare	Low	☑					☐
2	Mixing of PolyC...	Personal injury and Inhalation of fine particles, and/or skin and eye irritation.	Wearing ear plugs, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves) and taking regular breaks and good housekeeping. Adequate ventilation, limiting access of persons to the area during the activity and being aware of medical resources (first aid kits, emergency phone numbers)	Insignifica	Rare	Low	☑					☐

3	Physical injury ...	Injury to self (back and/or neck)	Proper lifting techniques, maximum solo lifting limit 20kg. Limiting access of persons to the area during activity and being aware of medical resources (first aid kits, emergency phone numbers). Regular breaks, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves) being aware of the surroundings and good housekeeping.	Insignifica	Possible	Low	☑					☐
4	Compaction sta..	Hearing loss, pinching of limbs and personal injury.	Wearing ear plugs, opening doors to allow sound to travel outside and taking regular breaks. Awareness of pinch points, people and surroundings and taking regular breaks. Limiting access of persons to the area during the activity, being aware of medical resources (first aid kits, emergency phone numbers) and good housekeeping.	Insignifica	Possible	Low	☑					☐
5	Using CBR Load...	Crushing of limbs from machinery	Proper usage of machinery, awareness of: pinch points, people and surroundings. Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves). Having a spotter encase something is to happen, Limiting access of persons to the area during activity, being aware of medical resources (first aid kits, emergency phone numbers) and good housekeeping.	Moderate	Unlikely	Mediu...	☐	Limit amount of work per day to reduce repetitive stress injuries, having a spotter encase something is to happen.	Moderate	Rare	Low	☑

Step 5 - Action Plan (for controls not already in place)

	Additional Controls:	*Exclude from Action Plan: (repeated control)*	*Resources:*	*Persons Responsible:*	*Proposed Implementation Date:*
5	Limit amount of work per day to reduce repetitive stress injuries, having a spotter encase something is to happen.	☐			

Supporting Attachments

No file attached

Step 6 – Request Approval

Drafters Name: *Scott Jackson*

Draft Date: *8/04/2016*

Drafters Comments:

Assessment Approval: All risks are marked as ALARP

Maximum Residual Risk Level: Low - Manager/Supervisor Approval Required

Approver: *Yan Zhuge*

Supervisor: (optional - for notification of Risk Assessment only) *Yan Zhuge*

Document Status: *Approve*

Step 6 – Approval

Approvers Name: *Yan Zhuge*

Approvers Position Title:

Approvers Comments: *All activities are low risk and standard lab testing*

I am satisfied that the risks are as low as reasonably practicable and that the resources required will be provided.

Approval Decision: Approve

Approve / Reject Date: *18/04/2016*

Document Status: *Approve*

B5: Compressive Strength Test with PolyCom, Recycled Road Profile and Concrete

University of Southern Queensland   Print View

UNIVERSITY OF SOUTHERN QUEENSLAND

USQ Safety Risk Management System

Safety Risk Management Plan

Risk Management Plan ID:	Status:	Current User:	Author:	Supervisor:	Approver:
RMP_2016_301	Approve	i:0#.w|usq\u1043993	i:0#.w|usq\u1043993	i:0#.w|usq\zhuge	i:0#.w|usq\zhuge

Assessment Title:	Development of a sustainable footpath material utilising recycled road profile, natural soils and PolyCom Stabilising Aid.	Assessment Date:	8/04/2016
Workplace (Division/Faculty/Section):	Faculty of Health, Engineering and Sciences	Review Date:	25/04/2016 (5 years maximum)

Context

DESCRIPTION:

What is the task/event/purchase/project/procedure?	Compressive Strength Test with Polycom, Recycled road profile and Concrete		
Why is it being conducted?	Research project		
Where is it being conducted?	Springfield engineering laboratories		
Course code (if applicable)	ENG4111 and ENG4112	Chemical Name (if applicable)	

WHAT ARE THE NOMINAL CONDITIONS?

Personnel involved	Scott Jackson
Equipment	Rammer, Moulds, Scales and Compression machine
Environment	Engineering laboratories
Other	
Briefly explain the procedure/process	Mixing the soils with the right amount of Recycled road profile and PolyCom so that the sample can be compacted. As per AS 1289.5.2.1-2003, Wetting soil samples with water and using the modified rammer to compact soils into moulds with 25 blows for 5 layers. Removal of the soils from moulds is needed, and once removed, the soils will be placed in the compression machine to be crushed until failure.

Assessment Team - who is conducting the assessment?

Assessor(s):	Krystal Kumar (0061047892)
Others consulted: (eg elected health and safety representative, other personnel exposed to risks)	

Risk Register and Analysis

	Step 1	Step 2	Step 2a	Step 3				Step 4				
	Hazards: From step 1 or more if identified	*The Risk:* What can happen if exposed to the hazard with existing controls in place?	*Existing Controls:* What are the existing controls that are already in place?	*Risk Assessment:* Consequence x Probability = Risk Level				*Additional Controls:* Enter additional controls if required to reduce the risk level	*Risk assessment with additional controls:* Has the consequence or probability changed?			
				Consequence	*Probability*	*Risk Level*	*ALARP*		*Consequence*	*Probability*	*Risk Level*	*ALARP*
	Example											
	Working in temperatures over 35° C	*Heat stress/heat stroke/exhaustion leading to serious personal injury/death*	*Regular breaks, chilled water available, loose clothing, fatigue management policy.*	*catastrophic*	*possible*	*high*	*No*	*temporary shade shelters, essential tasks only, close supervision, buddy system*	*catastrophic*	*unlikely*	*mod*	*Yes*
1	Soil handling	Inhalation of fine particles, and/or skin and eye irritation.	Adequate ventilation, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves). Limiting access of persons to the area during activity, being aware of medical resources (first aid kits, emergency phone numbers) and good housekeeping.	Insignifica	Rare	Low	☑					☐
2	Mixing of PolyC...	Personal injury and Inhalation of fine particles, and/or skin and eye irritation.	Wearing ear plugs, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves) and taking regular breaks and good housekeeping. Adequate ventilation, limiting access of persons to the area during the activity and being aware of medical resources (first aid kits, emergency phone numbers)	Insignifica	Rare	Low	☑					☐

3	Physical injury ...	Injury to self (back and/or neck)	Proper lifting techniques, maximum solo lifting limit 20kg. Limiting access of persons to the area during activity and being aware of medical resources (first aid kits, emergency phone numbers). Regular breaks, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves) being aware of the surroundings and good housekeeping.	Insignifica	Possible	Low	☑					☐
5	Compression m..	Crushing of limbs from machinery	Proper usage of machinery, awareness of: pinch points, people and surroundings. Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves). Limiting access of persons to the area during the activity, being aware of medical resources (first aid kits, emergency phone numbers) and good housekeeping.	Moderate	Unlikely	Mediu...	☐	Limit amount of work per day to reduce repetitive stress injuries, having a spotter encase something is to happen.	Moderate	Rare	Low	☑

Step 5 - Action Plan (for controls not already in place)

	Additional Controls:	*Exclude from Action Plan: (repeated control)*	*Resources:*	*Persons Responsible:*	*Proposed Implementation Date:*
5	Limit amount of work per day to reduce repetitive stress injuries, having a spotter encase something is to happen.	☐			

Supporting Attachments

No file attached

Step 6 – Request Approval

Drafters Name:	*Scott Jackson*	*Draft Date:*	*8/04/2016*
Drafters Comments:			

Assessment Approval: All risks are marked as ALARP

Maximum Residual Risk Level: Low - Manager/Supervisor Approval Required

Approver: *Yan Zhuge*	*Supervisor: (optional - for notification of Risk Assessment only)* *Yan Zhuge*	*Document Status:*	*Approve*

Step 6 – Approval

Approvers Name:	*Yan Zhuge*	*Approvers Position Title:*	*A/Prof*
Approvers Comments:	*All activities are low risk and standard lab testing*		

I am satisfied that the risks are as low as reasonably practicable and that the resources required will be provided.

Approval Decision: Approve	*Approve / Reject Date:* *18/04/2016*	*Document Status:*	*Approve*

B6: Slip Resistance Test with PolyCom and Recycled Road Profile

University of Southern Queensland — Print View

USQ Safety Risk Management System

Safety Risk Management Plan

Risk Management Plan ID:	Status:	Current User:	Author:	Supervisor:	Approver:
RMP_2016_300	*Approve*	i:0#.w|usq\u1043993	i:0#.w|usq\u1043993	i:0#.w|usq\zhuge	i:0#.w|usq\zhuge

Assessment Title:	Development of a sustainable footpath material utilising recycled road profile, natural soils and PolyCom Stabilising Aid.	Assessment Date:	8/04/2016
Workplace (Division/Faculty/Section):	Faculty of Health, Engineering and Sciences	Review Date:	25/04/2016 (5 years maximum)

Context

DESCRIPTION:

What is the task/event/purchase/project/procedure?	Slip Resistance Test with Polycom and Recycled road profile
Why is it being conducted?	Research project
Where is it being conducted?	Springfield engineering laboratories
Course code (if applicable)	ENG4111 and ENG4112
Chemical Name (if applicable)	

WHAT ARE THE NOMINAL CONDITIONS?

Personnel involved	Scott Jackson
Equipment	Rammer, Moulds, Scales and Slip resistance pendulum
Environment	Engineering laboratories
Other	
Briefly explain the procedure/process	Mixing the soils with the right amount of Recycled road profile and PolyCom so that the samples can be compacted. Wetting soils samples with water then using the modified rammer to compact soils into a square mould suitable for the test as close as possible to AS 1289.5.2.1-2003. Using the slip resistance pendulum to determine the British pendulum number.

Assessment Team - who is conducting the assessment?

Assessor(s):	Krystal Kumar (0061047892)
Others consulted: (eg elected health and safety representative, other personnel exposed to risks)	

Risk Register and Analysis

	Step 1	Step 2	Step 2a	Step 3				Step 4				
	Hazards: From step 1 or more if identified	*The Risk:* What can happen if exposed to the hazard with existing controls in place?	*Existing Controls:* What are the existing controls that are already in place?	*Risk Assessment:* Consequence x Probability = Risk Level				*Additional Controls:* Enter additional controls if required to reduce the risk level	*Risk assessment with additional controls:* Has the consequence or probability changed?			
				Consequence	*Probability*	*Risk Level*	*ALARP*		*Consequence*	*Probability*	*Risk Level*	*ALARP*
	Example											
	Working in temperatures over 35° C	*Heat stress/heat stroke/exhaustion leading to serious personal injury/death*	*Regular breaks, chilled water available, loose clothing, fatigue management policy.*	*catastrophic*	*possible*	*high*	*No*	*temporary shade shelters, essential tasks only, close supervision, buddy system*	*catastrophic*	*unlikely*	*mod*	*Yes*
1	Soil handling	Inhalation of fine particles, and/or skin and eye irritation.	Adequate ventilation, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves). Limiting access of persons to the area during activity, being aware of medical resources (first aid kits, emergency phone numbers) and good housekeeping.	Insignifica	Rare	Low	☑					☐
2	Mixing of Recy...	Personal injury and Inhalation of fine particles, and/or skin and eye irritation.	Wearing ear plugs, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves), taking regular breaks and good housekeeping. Adequate ventilation, awareness of surroundings and medical resources.	Insignifica	Rare	Low	☑					☐

3	Mixing of PolyC...	Personal injury and Inhalation of fine particles, and/or skin and eye irritation.	Wearing ear plugs, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves) and taking regular breaks and good housekeeping. Adequate ventilation, limiting access of persons to the area during the activity and being aware of medical resources (first aid kits, emergency phone numbers)	Insignifica	Rare	Low	☑					☐
4	Physical injury ...	Injury to self (back and/or neck)	Proper lifting techniques, maximum solo lifting limit 20kg. Limiting access of persons to the area during activity and being aware of medical resources (first aid kits, emergency phone numbers). Regular breaks, Wearing PPE (i.e. face masks, long trousers, safety glasses and gloves) being aware of the surroundings and good housekeeping.	Insignifica	Possible	Low	☑					☐
5	Compaction sta...	Hearing loss, pinching of limbs and personal injury.	Wearing ear plugs, opening doors to allow sound to travel outside and taking regular breaks. Awareness of pinch points, people and surroundings and taking regular breaks. Limiting access of persons to the area during the activity, being aware of medical resources (first aid kits, emergency phone numbers) and good housekeeping.	Insignifica	Possible	Low	☑					☐
6	Using slip resist...	Injury to self	Take regular breaks, and have awareness of pinch points, people and surroundings. Limiting access of persons to the area during activity and being aware of medical resources (first aid kits, emergency phone numbers) and good housekeeping.	Insignifica	Rare	Low	☑					☐

Step 5 - Action Plan (for controls not already in place)

	Additional Controls:	*Exclude from Action Plan: (repeated control)*	*Resources:*	*Persons Responsible:*	*Proposed Implementation Date:*

Supporting Attachments

No file attached

Step 6 – Request Approval

Drafters Name:	*Scott Jackson*	*Draft Date:*	*8/04/2016*
Drafters Comments:			

Assessment Approval: All risks are marked as ALARP

Maximum Residual Risk Level: Low - Manager/Supervisor Approval Required

Approver: *Yan Zhuge*	*Supervisor: (optional - for notification of Risk Assessment only)* *Yan Zhuge*	*Document Status:*	*Approve*

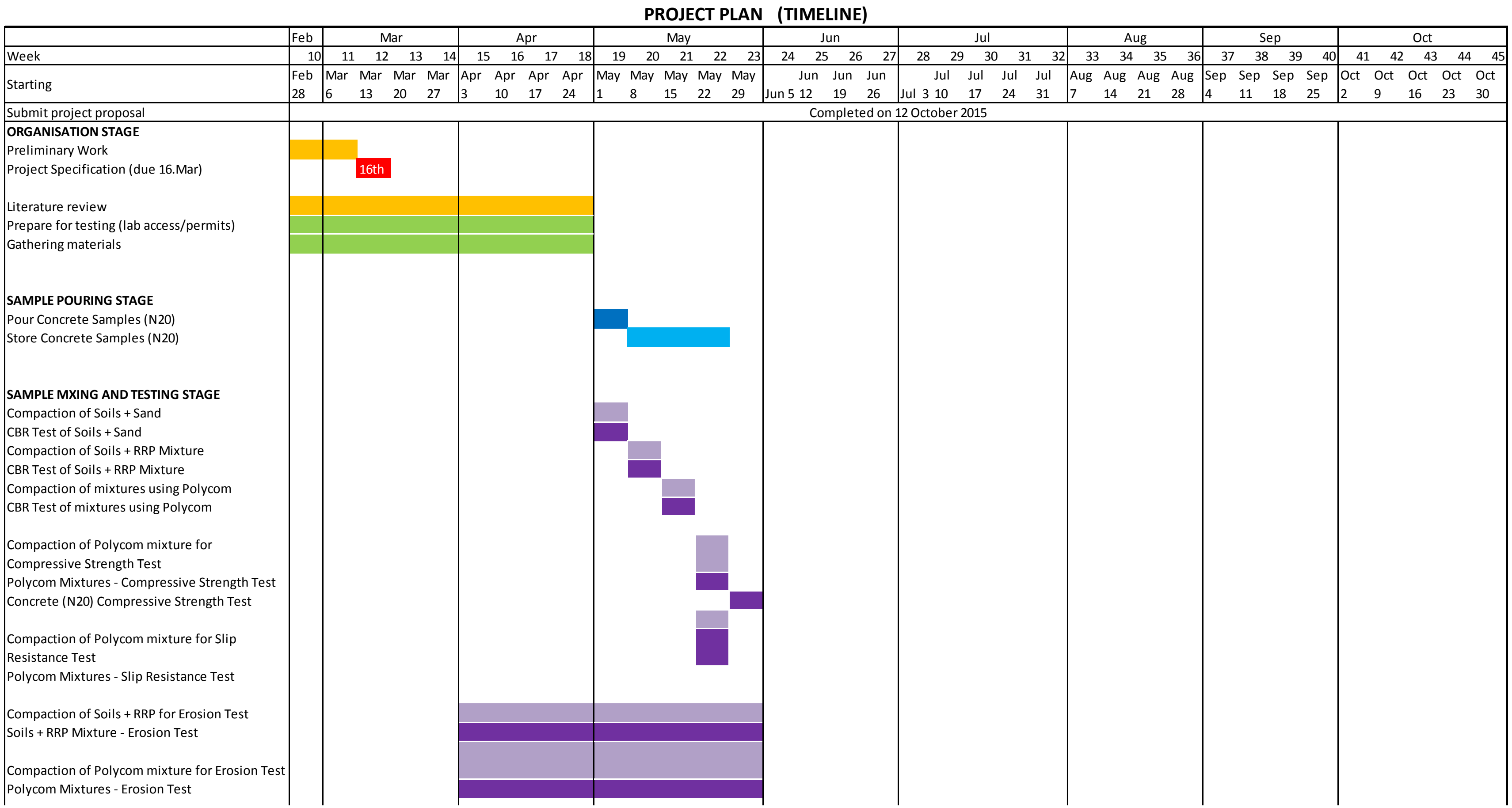
Step 6 – Approval

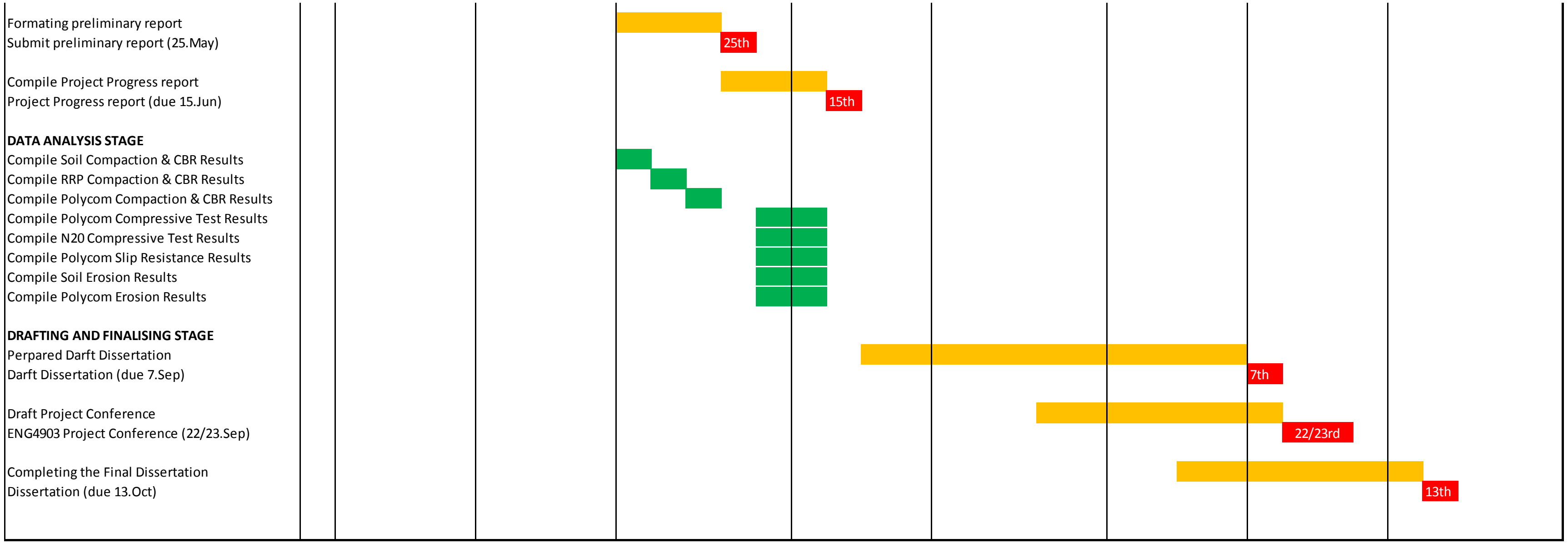
Approvers Name:	*Yan Zhuge*	*Approvers Position Title:*	*A/Prof*
Approvers Comments:	*All activities are low risk and standard lab testing*		

I am satisfied that the risks are as low as reasonably practicable and that the resources required will be provided.

Approval Decision: Approve	*Approve / Reject Date:* *18/04/2016*	*Document Status:*	*Approve*

APPENDIX C – PROJECT TIMELINE




Formating preliminary report
Submit preliminary report (25.May)
25th
Compile Project Progress report
Project Progress report (due 15.Jun)
15th
DATA ANALYSIS STAGE
Compile Soil Compaction & CBR Results
Compile RRP Compaction & CBR Results
Compile Polycom Compaction & CBR Results
Compile Polycom Compressive Test Results
Compile N20 Compressive Test Results
Compile Polycom Slip Resistance Results
Compile Soil Erosion Results
Compile Polycom Erosion Results
DRAFTING AND FINALISING STAGE
Perpared Darft Dissertation
Darft Dissertation (due 7.Sep)
7th
Draft Project Conference
ENG4903 Project Conference (22/23.Sep)
22/23rd
Completing the Final Dissertation
Dissertation (due 13.Oct)
13th

APPENDIX D – RESOURCES PLANNING

RESOURCE	QUANTITY	SUPPLIER	SPECIAL REQUIREMENTS
Vertosols	$0.03m^3$ or 50kg	Ipswich City Council	Council Permit
Hydrosols	$0.03m^3$ or 50kg	Ipswich City Council	Council Permit
Kandosols	$0.03m^3$ or 50kg	Ipswich City Council	Council Permit
Sodosols	$0.03m^3$ or 50kg	Ipswich City Council	Council Permit
Chromosols	$0.03m^3$ or 50kg	Ipswich City Council	Council Permit
Dermosols	$0.03m^3$ or 50kg	Ipswich City Council	Council Permit
Bedding sand	$0.03m^3$ or 50kg	Ipswich City Council	NA
Recycled Road Profile	$0.05m^3$ or 125kg	Ipswich City Council	NA
PolyCom Stabilising Aid (2L Bottle)	1	SEALS Group Pty Ltd	Nil
N25 Concrete (20 Kg Bag)	2	Scott Jackson	NA
Water	Unlimited	Scott Jackson	NA
Sieve (Size 19)	1	USQ	NA
Moulds for CBR and Compaction Tests	3 / 4	USQ	NA
Moulds for Erosion Tests	7	Scott Jackson	NA

Moulds for Slip Resistance Tests	7	Scott Jackson	NA
Moulds for Compressive Strength Tests	8	USQ	NA
Scales	1	USQ	NA
Beaker	1	USQ	NA
Oven safe dishes	6	USQ	NA
Water Pumps	2 +	Scott Jackson	NA
Tubing for water pumps	2 Metres	Scott Jackson	NA
Zip ties / hose clamps	4	Scott Jackson	NA
Coffee Filters	28	Scott Jackson	NA
Containers (Size as needed)	6	Scott Jackson	NA
Compaction Test Equipment	1	USQ Springfield Campus	Access to Laboratory
Drying Oven	1	USQ Springfield Campus	Access to Laboratory
CBR Testing Machine	1	USQ Campus Springfield/Toowoomba	Access to Laboratory
Compressive Strength Testing Machine	1	USQ Springfield Campus	Access to Laboratory
Slip Resistance	1	USQ Springfield Campus	Access to Laboratory
Triaxial Shear Test Machine	1	USQ Springfield Campus	Access to Laboratory
Sand Cone Test	1	USQ Springfield Campus	Access to Laboratory