University of Southern Queensland

Faculty of Health Engineering and Sciences

Dissertation

Determine the optimum cementitious blends to be used on pavement rehabilitation treatment.

Submitted by

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Abstract.

Keywords: Pavement, rehabilitation, cement powder.

The road network is required to be robust yet flexible enough to withstand a variety of traffic loads while delivering a level of comfort the public expect (UniSQ, 2020a). Poorly maintained roads are said to cause up to 1.2 million deaths and 50 million injuries annually (Peden, 2004). Unbound granular pavements with a double/double seal as a wearing course are common in Australia. This study is to focus on the rehabilitation of rural roads that have been constructed and are repaired in this way. It will look at the effectiveness of adding a stabilisation agent, such as cement powder during works.

This study aims to determine the ideal amount of cement powder required to give the optimal Californian bearing ratio (CBR) results for road repairs. Both economic and sustainable benefits are the expected outcome of this report. Several studies focused on Unconfined Compressive Test (UCS) were found during the literature review, although there was a limited amount of information specifically addressing CBR, especially in the context of the Darling Downs flood plains.

As this project is located around Dalby, the availability of Transport and Main roads (TMR) approved quarries is limited. It was decided to focus attention on the main supplier RSC Quarry 20 kilometres north of Dalby.

UniSQ had all equipment available to perform the testing. A sample of the common material used in road rehabilitation was obtained. The Quarry was able to supply results from their own quality testing.

TMR research, in terms of UCS, determined that 1.65% added cement powder gave the best results. Using this it was decided to complete CBR tests at six different levels, 0% 0.5%, 1%1.5%, 2% and 2.5%, refer to figure 1, and compare results with the TMR UCS results.

The addition of more cement powder was found to make the material more brittle. Unfortunately, a pavement layer that is brittle is not desirable. This means that adding too much cement is not only costly but also harmful to the environment. To explore alternatives, we need to conduct further research to determine if using an eco-friendly cement powder yields different outcomes.

The results of this study have validated the use of the UCS test and show that good CBR results are obtained with the use of similar added cement. This will help with determining a quantity of additive that design engineers allow for rehabilitation work.

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

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Richard Honan.

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Glossary of Terms.

AADT	Average annual daily traffic
BOM	Australian Government Bureau of Meteorology
CBR	California Bearing Ratio Test
DTMR or TMR	Department of Transport and Main Roads
GP Cement	General Purpose Cement
MDD	Maximum Dry Density
MTM	Materials Testing Manual
OMC	Optimum Moisture Content
RHA	Rice Husk Ash
RSA	RSA Construction Materials
UCS	Unconfined Compressive Strength
USQ or UniSQ	The University of Southern Queensland
USC	Unconfined compressive strength.
WHO	World Health Organisation

1 Introduction.

The construction of the road network requires materials that are both flexible enough to withstand a variety of traffic loads, and stable enough to uphold a level of comfort the general public have come to expect (UniSQ, 2020a).

Poorly maintained roads can become dangerous to use. According to the WHO as many as 1.2 million people are killed 50 million are injured annually (Peden, 2004). Death and injury need to be minimised, and road maintenance is one piece of the puzzle.

Unbound granular pavements with sprayed seal surfaces are a common type of pavement used in rural Australia, making up approximately 90% of all surfaced roads. These pavements are typically made up of layers of engineered crushed rock or gravel, which are compacted to form a stable base for the road surface (Austroads, 2021).

The research conducted in this paper identifies the most productive way to rehabilitate or rebuild existing roads. There are many different types of treatments carried out, but the focus will be on cement stabilisation, shown in Figure 1, of granular sub grade within the Darling Downs area.

Figure 1 Cement powder spreading.

1.1 Idea for the study.

In the local area, it has been observed that the challenge of delivering durable and good quality roads is both arduous and costly. The main highway, known as the Warrego Highway, underwent significant construction in the town of Dalby in late 2018. Although this section of road does not exhibit any visible cracks, it is experiencing vertical movement.

This study is to focus on the reconstruction of flexible pavements and its connection to the CBR test. The final question was developed after consulting with experts including Mike Harris, a consulting engineer in Toowoomba, Dr. David Thorpe, an Associate Professor at the University of Southern Queensland, and Belinda Waters, a Materials Technologist at TMR. This paper will focus on highways with an AADT between 500 and 10 000 vehicles per day (Qld globe, 2023).

1.2 Aim and scope of the study.

While a body of research relating to this subject is available, most of this has been in connection with the UCS testing and the strength produced in the pavement. There is a limited in this area focusing on the bearing capacity of granular materials. To help with available time for this research, focus will be confined to the geographic area of Dalby, in the state of Queensland, Australia and surrounding areas.

The aim of this dissertation is to investigate the relationship between the quantity of cement powder added to the granular pavement and its material properties as they relate to road building.

Results from this research will contribute to in the development of guidelines for the optimal use of cement powder in granular pavements while road building around Dalby.

1.3 Types of binders.

There are multiple versions of pavement stabilisation available in Australia. These are shown in Table 1. In The Austroads guide to Pavement technology, 2019 part 4D, several materials and techniques are mentioned, including cementitious blends, lime, emulsified bitumen, foamed bitumen, mixing of granular materials, and various chemical products (Austroads, 2019). In the area of research TMR typically use cementitious blends in pavement rehabilitation. This research will aim to identify the optimum use of cementitious blends.

Table 1 Stabilisation types.

Stabilisation binder/additive	Stabilising action	Stabilisation effect	Applicable material types
Cement	• Cementitious inter-particle bonds are developed	• Low binder content (< 2%): decreases susceptibility to moisture changes, resulting in modified materials • High binder content: increases modulus and tensile strength significantly, resulting in bound materials	• Not limited apart from materials which contain deleterious components (organics, sulphates, etc.) which retard cement reactions Suitable for granular • materials but inefficient in predominantly one-sized materials and heavy clays May be suitable for • low-plasticity soils that are not reactive to lime
Cementitious blends	• Cementitious inter-particle bonds are developed but rate of development is slow compared to cement	• Generally, like cement but rate of gain of strength similar to lime Generally, reduces • shrinkage cracking compared to cement	• Similar to cement
Lime	• Cementitious inter-particle bonds are developed but rate of development is slow compared to cement	• Improves handling properties of cohesive materials and initial strength Higher binder content: long- • term increases in CBR, modulus and tensile strength	• Suitable to modify granular materials with high plasticity using lower binder contents Suitable to stabilise • cohesive subgrade soils in the long-term if higher binder contents used Requires clay components • in the soil/gravel that will react with lime Organic materials will retard • reactions
Bitumen (emulsion)	• Agglomeration of fine particles	• Decreases permeability and improves cohesive strength • Decreases moisture sensitivity by coating fines	• Applicable to granular materials with low cohesion and low plasticity
Bitumen (foamed)	• Inter-particle bonds are developed due to bitumen and secondary binders	• Increases modulus and tensile strength significantly, resulting in bound materials	• Applicable to granular materials with low cohesion and low plasticity
Granular material	• Mixing two or more materials to achieve target PSD and plasticity	• Some changes to material strength, permeability, volume stability and compactability • Materials remain granular	• Poorly-graded soils and natural gravels with a deficiency in the particle shape, PSD or plasticity
Other proprietary chemical products	• Agglomeration of fine particles and/or chemical bonding (refer trade literature)	• Typically, increased dry strength, changes in permeability and volume stability	• Typically, poorly-graded soils and gravels

1.4 Objectives of the project.

- Quantify how the bearing capacity of pavement with different quantities of cement powder added to the granular base layer.
- To develop a graph showing the optimum additive needed.
- Compare results gained with the how testing and treatments are carried out now.

1.5 Location of research.

This research is to be carried out within the TMR Darling Downs District. The focus will be on extremely reactive clay subgrade material. This can be found around Dalby and Cecil Plains. Both towns shown in Figure 2 are located approximately 200 kilometres west of Brisbane the capital of Queensland, Australia (Qld globe, 2023).

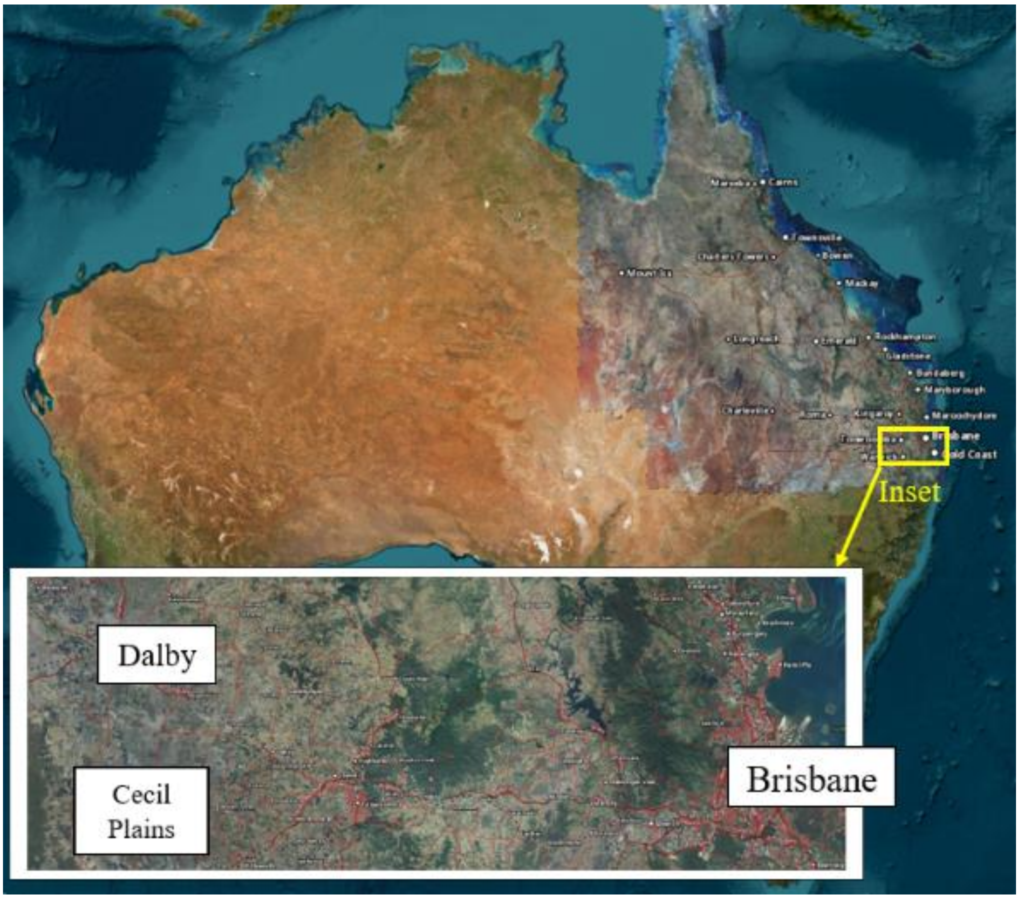

Figure 2 Locations (Qld globe, 2023) .

This area is predominately black soil plains. According to French, building of roads in this soil type can be a challenge (French, 2010). Black soil or clay is classified as extremely reactive.

In Table 2 below it shows there is more than 75mm in the characteristic ground movement (Geotech Solutions, 2011).

Table 2 General Definition of site Classes.

Site Class	Foundation	Characteristic Surface Movement
A	Most sand and rock sites with little or no ground movement from moisture changes	
S	Slightly reactive clay sites, which may experience only slight ground movement from moisture changes	0 - 20mm
M	Moderately reactive clay or silt sites, which may experience moderate ground movement from moisture changes	20 - 40mm
H1	Highly reactive clay sites, which may experience high ground movement from moisture changes	40 - 60mm
H2	Highly reactive clay sites, which may experience very high ground movement from moisture changes	60 - 75mm
E	Extremely reactive sites, which may experience extreme ground movement from moisture changes	> 75mm
P	Sites which include filled sites (refer to AS 2870 2.4.6), soft soils, such as soft clay or silt or loose sands; landslip; mine subsidence; collapsing soils; soils subject to erosion; reactive sites subject to abnormal moisture conditions or sites which cannot be classified otherwise.	

1.6 Problem statement.

The local road network needs constant repair. This research will identify techniques to limit maintenance and to identify the most economical process.

A subgrade, or natural ground, with a CBR value of less than 3% is considered as soft and requires some treatment (Austroads, 2021). The area around Dalby and Cecil Plains has generally have CBR values lower than this. Treatment of the subgrade layer is timely and expensive, therefore this is predominantly carried out on newly constructed roads and not on a rehabilitation job. When repairing a road, cost and time restraints limit the opportunity to treat the subgrade layer. Working an open road requires repairs to be carried out on one lane at a time so the impact to traffic flow is minimised. When working on a lane it is optimal to have this open at the end of each shift.

As stabilisation treatment has a multitude of positive outcomes, this study will limit research to the effect on the modulus or the bearing capacity of the granular material using the CBR test.

1.7 Expected outcomes and benefits.

The benefit from this research is expected to be economically driven. Environmental sustainability will also be considered. It is anticipated that this attribute will have a lower impact on the longevity of any road network that adopts the results. Whilst saying this the care for the planet is a serious concern.

2 Background and Literature Review.

Around the world there are two types of common road pavements. These are rigid and flexible pavements. Unlike rigid pavements, which consist of a concrete layer over a base layer, flexible pavements are composed of multiple layers of granular materials, such as gravel, sand, or crushed rock, that can be bound together by a bituminous or cementitious binder. This paper is only concerned with flexible pavements and the flexibility within the granular layer. Background knowledge for this project was gained during a literature review. This was to showcase significant research on this topic and highlight any areas that need further studies. The academic community has previously achieved significant advancements in the examination of the mechanical characteristics of cement-stabilized materials, as evidenced by the research conducted by Wang and colleagues (Wang et al. 2022).

Areas considered within this literature review were:

1. Natural Attributes.
2. How do organics effect mechanical properties of soils?
3. Increased strength.
4. Longevity of repair.
5. Traffic Loading.

2.1 Natural Attributes: Effects of Temperature and Moisture on Pavement Design.

The most relevant attributes affecting the performance of pavement design is temperature and moisture (UniSQ, 2020b). When adding a stabilising agent such as cement powder, the impact from both factors are reduced (Wang et al. 2018). This paper is concerned with low temperatures and suggests this factor is also improved with cement added to pavements. Wang also suggests the expansion of water when freezing will cause heaving throughout the pavement. Within the area this study is concerned with low temperature, below freezing, is not common and should not influence the results. Table 3 below shows the lowest recorded air temperature since 1992 as 0.4^0C in July of 2002 (BOM, 2023).

Table 3 Minimum Temperatures at Dalby (BOM, 2023).

Station: Dalby Airport

Number: 41522 Opened: 1992 Now: Open Details

Lat: 27.16° S Lon: 151.26° E Elevation: 346 m

Lowest

Key: Units = °C. *12.3* = Not quality controlled or uncertain, or precise date unknown

Period for calculating statistics: All years 1961-1990

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Graph													
1992	19.3	19.0	15.5	12.8	9.2	2.8	2.2	4.2	7.2	9.8	14.5	17.0	11.1
1993	19.2	18.5	15.0	12.0	9.6	4.5	8.9	5.1	9.0	12.4	15.5	16.7	12.2
1994	19.2	18.3	14.8	12.2	6.3	3.4	1.3	2.3	5.7	11.0	15.5	16.9	10.6
1995	18.1	18.5	16.2	10.1	10.7	6.5	2.8	4.1	8.8	12.8	17.1	17.2	11.9
1996	19.5	16.8	14.6	10.8	10.7	7.2	3.5	5.4	6.9	12.3	14.1	16.8	11.6
1997	17.1	19.8	16.1	11.5	10.4	4.6	3.8	3.7	9.9	13.0	17.3	19.6	12.2
1998	19.6	19.8	17.1	14.5	9.9	6.0	7.0	8.8	11.7	12.2	14.4	17.5	13.2
1999	18.5	17.9	17.5	10.9	9.7	5.2	6.3	5.7	8.6	13.9	13.5	15.4	11.9
2000	17.0	16.2	16.6	14.0	8.6	4.4	2.9	4.8	9.3	13.4	15.6	18.4	11.8
2001	19.1	18.0	18.2	13.2	6.5	[illegible]	[illegible]	3.1	9.1	12.5	15.3	18.7	12.0
2002	18.7	19.3	16.9	13.0	7.3	[illegible]	0.4	6.0	9.3	13.0	16.7	17.2	12.0
2003	17.7	19.6	16.6	13.4	8.5	[illegible]	[illegible]	6.0	8.3	11.5	14.4	18.1	12.2
2004	20.0	20.0	17.0	14.3	7.2	3.5	3.1	3.9	7.9	13.6	16.0	18.5	12.1
2005	19.3	18.5	16.0	13.9	7.5	8.8	6.2	4.5	9.9	15.6	17.2	19.5	13.1
2006	20.6	19.9	16.9	13.8	5.9	4.5	4.8	3.9	9.8	13.2	15.5	16.0	12.1
2007	18.8	18.0	16.6	12.6	10.3	6.1	1.7	6.9	8.1	13.9	15.5	17.8	12.2
2008	18.6	17.7	13.5	8.7	5.9	5.8	4.9	2.4	10.5	11.8	15.6	17.3	11.1
2009	18.3	18.1	15.6	12.6	8.6	5.5	2.8	5.8	7.9	11.5	17.0	18.9	11.9
2010	18.3	19.3	17.1	13.6	7.8	5.5	6.2	5.8	12.0	13.0	15.4	18.3	12.7
2011	18.5	18.7	17.4	12.6	6.6	3.8	1.4	4.7	6.9	11.8	16.5	16.1	11.2
2012	17.7	17.8	15.6	12.1	6.1	6.4	4.8	2.7	7.1	11.5	15.6	17.8	11.3
2013	19.7	17.1	16.8	11.0	7.7	6.0	6.5	3.9	9.2	12.2	14.7	16.5	11.8
2014	18.4	18.1	16.7	13.5	9.1	5.6	1.2	5.5	7.9	13.1	17.8	18.5	12.1
2015	19.0	17.4	17.5	11.3	8.2	6.5	3.8	3.9	6.8	12.3	17.4	16.8	11.7
2016	18.4	18.2	17.8	14.0	8.4	7.5	6.4	5.5	10.2	9.6	14.4	18.2	12.4
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2017	20.6	19.7	18.7	11.8	9.4	5.6	4.4	3.6	8.4	15.6	13.6	17.8	12.4
2018	18.7	18.5	17.0	13.2	7.4	3.9	3.6	2.6	8.6	14.5	14.8	17.3	11.7
2019	18.7	18.4	18.6	13.2	8.5	4.9	3.1	4.6	7.3	12.7	15.5	17.9	11.9
2020	20.8	19.9	16.4	13.0	7.4	5.8	5.2	4.3	9.4	13.1	15.8	19.3	12.5
2021	17.9	17.8	17.5	10.9	7.5	5.4	5.0	5.4	7.9	13.1	16.0	17.6	11.8
2022	18.5	17.1	17.0	14.1	12.9	3.4	5.0	5.3	9.2	12.4	12.4	14.4	11.8

top

1992 Go View a year of daily data

There is evidence that the microstructural characteristics of soils change with the addition of cement. Wang suggests that the permeability decreases with both compaction and cement treatment. As hydration of the cement occurs the ability for water to ingress and weaken the pavement decreases (Wang et al. 2022). In general, the topography of the land in this area has very slight fall. During a rain event in the area water is slow to recede and water ingress of a pavement is of real concern here. Figure 3 represent the mapping of an extreme event within the area studied (Department of Resourses, 2023).

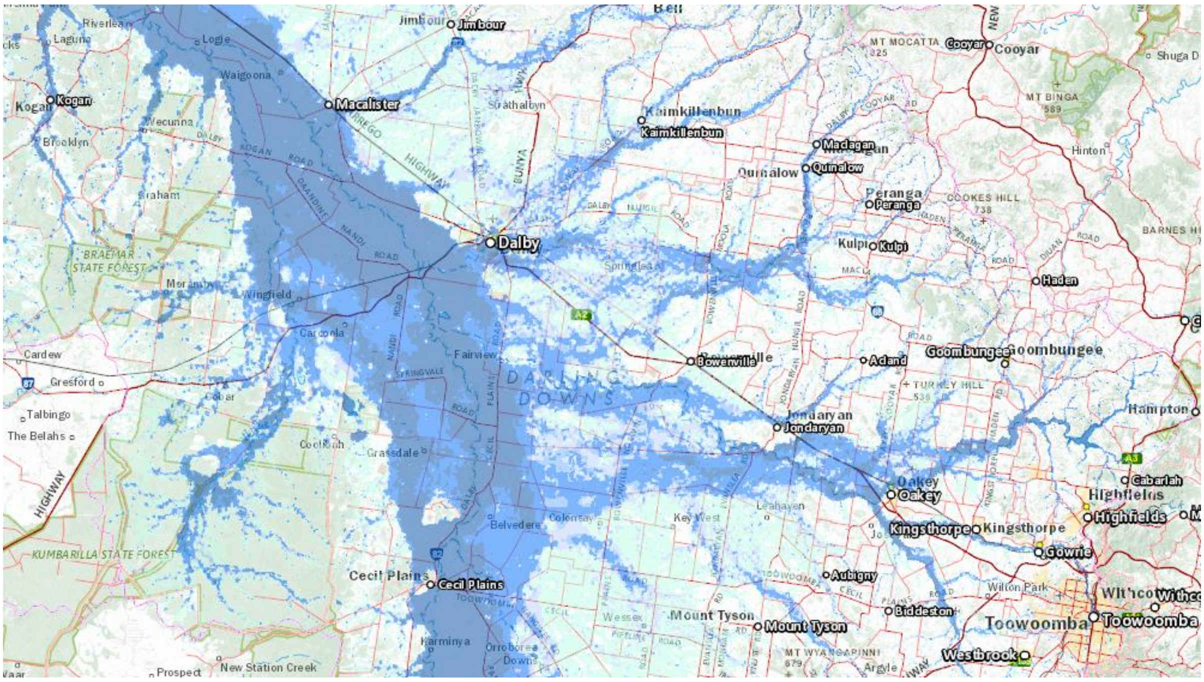

Figure 3 Flood mapping. (Department of Resourses, 2023)

2.2 How do organics affect mechanical properties of soils?

Organics are substances that contain carbon and hydrogen atoms, such as plant or animal matter (Hamouche & Zentar, 2020). Organics can be present in soils, including pavement material, naturally or artificially, such as from agricultural activities, industrial waste, or sewage sludge (Hamouche & Zentar, 2020). Organics can affect the mechanical properties of soils in various ways, including CBR values, quantity, and interaction with soil particles (Hamouche & Zentar, 2020)

Ogbuagu, 2018, has researched the possibility of using an organic substance such as RHA as a stabilising agent for soils with lower CBR value subgrades (Ogbuagu et al. 2018). The paper suggests using this abundant waste product should reduce the threat to the environment and ecosystem. Positive results were obtained with the improvement to the CBR values after 5% RHA was added the natural subgrade strengthened to an optimum value of 9.35% (Ogbuagu et al. 2018). While this is a study on the subgrade layer it is worth extra research to identify what effect RHA would have on granular material.

It is well known that limited organic matter should be used in any pavement layers and as RHA is organic questions are raised about the longevity of the results published. Hamouche, 2020, has mentioned that worldwide there is varying limits on the quantity of organics within pavements. This paper gives values of between 2% and 4%. The link with the evolution of organics is said to produce voids and therefore increase the compressibility of the pavement over time (Hamouche & Zentar, 2020).

Other studies have also explored the influence of organics on soil mechanical properties. For instance, Basha and Hashim, 2016, investigated the effect of sewage sludge on soil properties and found that the presence of organics increased the soil's plasticity and decreased its strength (Basha & Hashim, 2016). On the other hand, some studies have suggested that the addition of organic matter can enhance soil properties, such as water-holding capacity and fertility (Murphy, 2015). These conflicting results highlight the need for more research in this area.

As this research has a responsibility to find an environmentally sustainable method to increase CBR values, the use of organics was considered and investigated.

While using waste organic material can be both cost effective and environmentally friendly this literature review has found that reports on the effectiveness of using organics as a stabilisation agent are conflicting. The use of organics should not be considered in a pavement layer till further investigating is completed.

2.3 Increased strength.

It has been found that the inclusion of cement powder enhances the structural integrity of soils. Zhang, 2017, found that sandy material increased both in strength and bearing capacity. This paper tested both the UCS and CBR values with different quantities of added powder (Zhang et al. 2017). While the focus from Wang is on improving the likelihood of landslips, the results of this study provide positive outcomes and should corollate with the effectiveness on granular material.

Another paper from China states that addition of cement powder can significantly improve the mechanical properties of granular material on a roadway (Li et al. 2022). The caveat with this is that if the pavement is not flexible enough it can cause cracking in the surface by being too brittle as shown below in Figure 4 (Guthrie et al. 2007). As the subgrade material in this area has a low bearing capacity and this is a real possibility.

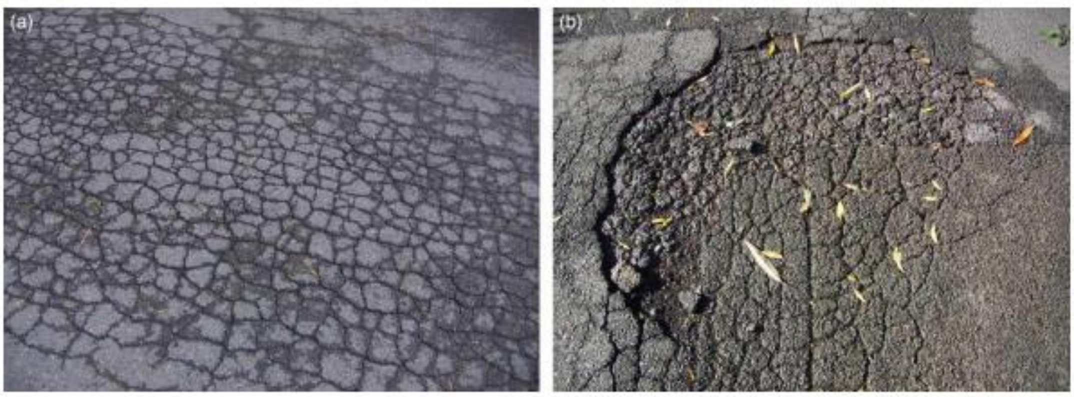

Figure 4 Examples of crocodile cracking (Croll 2009).

Example (a) in Figure 4 shows extensive primary cracking in a non-trafficable area of the road and (b) has the reflective cracking shown in two layers of seal.

2.4 Longevity of repair.

One of the main advantages of unbound granular pavements with sprayed seal surfaces is their low initial cost. These cost advantages are especially beneficial for rural communities with limited budgets for road infrastructure. They are also relatively easy to construct and maintain, making them an attractive option for many rural communities.

The longevity of any of these pavement repairs are crucial aspect to consider. It is necessary to prepare a cost analysis to ensure the economic and the environmental costs of the repair are feasible. Within the geographic area under consideration, it is noticed that the subsoil has low bearing capacity. The subsoil bearing capacity limitation imposes substantial challenges on pavement design and, by extension, on the durability and longevity of these infrastructure assets (Austroads, 2021).

However, these pavements also have some disadvantages that affect their longevity and performance over time. One of the main challenges is the susceptibility to moisture damage, which can cause loss of strength, deformation, cracking, and potholing of the pavement layer (Austroads, 2021). Moisture damage can be exacerbated by the presence of organics in the soil or prolonged flooding, as shown in section 2.2, which can reduce the bond between the aggregate and the binder. Other factors such as environmental factors, temperature variations, rainfall, and freeze-thaw cycles will also reduce the life of the repair (Hamouche & Zentar, 2020). Therefore, it is important to ensure adequate drainage and compaction of the pavement layer, as well as to apply timely maintenance treatments, such as resealing or patching, to prevent or repair moisture damage.

Another challenge is the longevity of the flexible pavement, this depends on the quality and quantity of the binder and the aggregate used, as well as on the traffic and climatic conditions (Austroads, 2021). The sprayed seal surface can deteriorate over time due to gradual hardening of the binder, which can cause loss of aggregate or minor surface cracking. These defects can expose the underlying pavement layer to water ingress and further deterioration. Therefore, it is important to select the appropriate type and grade of binder and aggregate for the sprayed seal surface, as well as to monitor and evaluate its performance periodically and apply preventive or corrective measures when needed.

According to Austroads, the typical design life of unbound granular pavements with sprayed seal surfaces is approximately 20 years, depending on the traffic volume and load, the pavement thickness and quality. The maintenance frequency and effectiveness of the treatment will directly impact the life of the road (Austroads, 2021). However, these pavements can be extended beyond their design life by applying rehabilitation or upgrading treatments, such as those mentioned in Table 1. These treatments can improve the strength, stiffness, durability, and resilience of the pavement layer, as well as reduce its permeability and susceptibility to moisture damage.

According to Austroads the use of cemented bases with sprayed seal surfaces are more commonly associated with the rehabilitation or upgrading of existing granular pavements, rather than in the context of totally new construction works (Austroads, 2021). This strategic choice is instrumental in extending the lifespan of road infrastructure, aligning with the imperative of achieving sustainable, long-term road design solutions.

Cement stabilisation has several advantages over other rehabilitation or upgrading treatments, such as:

- It can be applied to a wide range of soil types and gradations, including those with low bearing capacity (Wang et al. 2018).
- It can reduce the thickness of the pavement layer required to achieve a given level of performance, resulting in lower material and construction costs.
- It can improve the resistance of the pavement layer to deformation, cracking, fatigue, rutting, and erosion under traffic loads and environmental changes (Wang et al. 2018).
- It can reduce the permeability and susceptibility of the pavement layer to moisture damage by forming a rigid matrix that prevents water ingress and reduces void ratio (Wang et al. 2022).

However, cement stabilisation also has some disadvantages that need to be considered, such as:

- It requires careful selection and control of the cement content, water content, compaction level, curing time and conditions, and environmental factors to ensure optimal strength and durability of the cemented base layer (Wang et al. 2022) .
- It increases the brittleness and shrinkage of the pavement layer, which can lead to cracking and deterioration if not properly managed (Austroads, 2019) .
- It requires a suitable surface treatment to protect the cementitious base layer from weathering and abrasion. The most common surface treatment for cemented bases is a sprayed seal surface (Austroads, 2021).

The longevity of repair for cemented bases with sprayed seal surfaces depends on similar factors as it does for unbound granular pavements with sprayed seal surfaces, such as traffic volume and load, pavement thickness and quality, maintenance frequency and effectiveness, and environmental conditions. However, cemented bases with sprayed seal surfaces generally have a longer design life than unbound granular pavements with sprayed seal surfaces due to their higher strength and durability. According to Guthrie, 2007, the typical design life of cementitious bases with sprayed seal surfaces can be extended further by applying preventive or corrective maintenance treatments, such as resealing or patching, or by applying an asphalt overlay (Guthrie et al. 2007).

The longevity of repair for unbound granular pavements with sprayed seal surfaces and cementitious blended base with sprayed seal surfaces depends on several factors, such as the quality of materials and construction, the design and thickness of pavement layers, the traffic volume and load, and the climatic conditions. Both types of pavements require periodic monitoring and evaluation of their performance and timely maintenance interventions to prevent or repair deterioration and extend their lifespan. Cement stabilisation is a common and effective rehabilitation or upgrading treatment for unbound granular pavements with sprayed seal surfaces, as it can improve their strength, durability, and resilience, as well as reduce their thickness and permeability. However, cement stabilisation also has some drawbacks that need to be considered and managed, such as increased brittleness and shrinkage, and the need for a suitable surface treatment.

2.5 Traffic Loading.

Traffic loading is one of the most important factors affecting the performance and durability of pavement structures. Traffic loading refers to the magnitude, frequency, and distribution of the forces applied by vehicles on the pavement surface, which can cause stress, strain, deformation, fatigue, and damage to the pavement layers (Austroads, 2019). Traffic loading depends on various parameters, such as vehicle type, axle configuration, wheel load, tyre pressure, speed, and traffic volume and mix.

Traffic loading can have different effects on different types of pavement layers and materials. For flexible pavements, which consist of asphalt or bituminous layers over granular or stabilised base and subbase layers, traffic loading can cause rutting, cracking, and potholing due to permanent deformation or fatigue failure of the pavement layers (Austroads, 2019). For rigid pavements, which consist of concrete slabs over granular or stabilised base and subbase layers, traffic loading can cause cracking, spalling, faulting, and pumping due to flexural stress or differential settlement of the pavement layers.

Pavement rehabilitation is the process of restoring or improving the structural or functional condition of a deteriorated pavement. Pavement rehabilitation can involve different methods and techniques, such as patching, overlaying, recycling, or stabilising the existing pavement layers (Department of Transport and Main Roads, 2020). Pavement rehabilitation aims to extend the service life of the pavement, enhance its performance and safety, and reduce its maintenance costs and environmental impacts.

Cementitious blends are mixtures of cement with other hydraulic or pozzolanic materials, such as fly ash, slag, lime, or silica fume. Cementitious blends can be used as stabilising agents for pavement rehabilitation, as they can improve the strength, stiffness, durability, and resilience of the existing pavement materials (Wang et al. 2018). Cementitious blends can also reduce the thickness and permeability of the pavement layers, as well as their susceptibility to moisture damage and cracking (Department of Transport and Main Roads, 2020).

The optimum cementitious blends for pavement rehabilitation depend on several factors, such as the type and condition of the existing pavement materials, the desired properties and performance of the stabilised pavement layers, the availability and cost of the cementitious materials, and the environmental conditions and constraints. The optimum cementitious blends can be determined by conducting laboratory tests and field trials to evaluate the effects of different cementitious materials and proportions on the physical, mechanical, and chemical characteristics of the stabilised pavement materials (Wang et al. 2018).

3 Methodology.

The aim of this research is to identify the optimum cement to granular pavement mixture in terms of CBR values for road rehabilitation. This is focused on the Dalby flood plains and on sub-grades with low CBR values. It will try to find the best outcome while using the least cement powder. As the production of cement is said to contribute 6% of the world's greenhouse gasses (Ali1 et al. 2015) it would be pertinent to include a sustainable and environmental element.

3.1 Selected quarry material to be studied.

The area around Dalby has two main quarries in which granular material is sourced. The Tierney Crushing and Transport quarry Jondaryan is located 44 kilometres east-south-east of the town and RSA Construction Materials 20 kilometres north of Dalby. This paper will concentrate on material form the main quarry, RSA Construction Materials which is shown in Figure 5.

Figure 5 Quarry Locations.

3.2 CBR method.

Conducting a CBR test is a crucial component of this research project. The process for performing a CBR test according to both the AS 1289.2.1.1 (AS1289.2.1.1, 2005), TMR Q113A (Deptartment of Transport and Main Roads, 2022) and the study guide from USQ CIV39069 Civil material practice (UniSQ, 2021) involves the following general steps:

First, all necessary equipment should be gathered, including a CBR testing machine, a penetration piston, a load ring, a dial gauge, and a set of sieves, which are available at the USQ laboratory. Additionally, materials required include a soil sample for testing, and cement powder, lime, and flyash to incorporate. Due to time constraints, the research did not cover environmentally friendly cement. However, considering its importance for the well-being of humanity, it should be addressed soon.

The soil sample will be taken from the location where the CBR test will be conducted, RSA quarry in this case, and passed through a 19 mm sieve, removing any visible contaminants. As the tests are to be conducted on quarry produced type 2.3 road base a sieve test has been carried out previously. All material will need to be dried so it has a minimum moisture content. This way, regulation of the sample's water content can be managed. Next, a control sample with no added cement powder can be prepared. Then predetermined quantities of cementitious powder should be incorporated into the sample. The quantities that will be added include 0% as control, 0.5%, 1%, 1.5%, 2% and 2.5%.

At this point water is added at a predetermined amount and thoroughly mixed. To obtain a good result four (4) different moisture levels, three (3) lower than OMC and one greater than OMC, will be tested for each different quantities of cement added. The OMC of the material will be used from the information supplied in appendix F.

The specimen is compacted into the CBR cylinders, which consist of a cylindrical mould accompanied by a base plate and a top plate, The moulds will be metal of a known volume, with an internal diameter of 152±1 mm, height of 178±1 mm, and wall thickness of 5 mm. This mould will also have an extension collar and perforated metal base, as depicted in Figure 6 . The soil sample is added in three equal layers, compacting each layer with a rammer with 53 blows each layer.

As these tests are to be carried out on material with cement it was decided after compaction into the cylinders to allow the powder to hydrate and strengthen. Concrete is said to have approximately 70% of the final strength after seven (7) days of curing. This was a good approximation of the number of days it takes from start of repair to when the seal is in place inhibiting the curing process on site.

After curing the samples were tested. A consistent load is applied to the piston at a rate of 1.0±0.2 mm/min until the piston has penetrated the soil sample by 2.5 and 5.0 millimetres. If a computer-based machine is available, the computer records the load versus penetration depth, producing an output graph. If it is to be conducted with a manual CBR machine the penetrating piston is wound by hand. The load ring will produce values these are to be recorded by another person, this is so the piston is wound down at a consistent pace. A manual machine shown in Figure 7 was used for all testing conducted in this research thesis. The recordings from either machine can be converted into CBR values.

To calculate the CBR value, divide the load required for the 2.5 mm penetration depth by the load required for the same depth in a standard crushed rock material. This ratio represents the CBR value for the soil sample. To ensure accuracy and consistency of results, the test should be repeated with at least two additional soil samples.

Lastly, the CBR values obtained should be analysed to draw conclusions about the strength and suitability of the granular material for different applications. Standardized procedures in AS 1289.6.1.1 should be followed for all experiments. It is imperative to adhere to these procedures to ensure accurate and reliable results (AS1289.0, 2014).

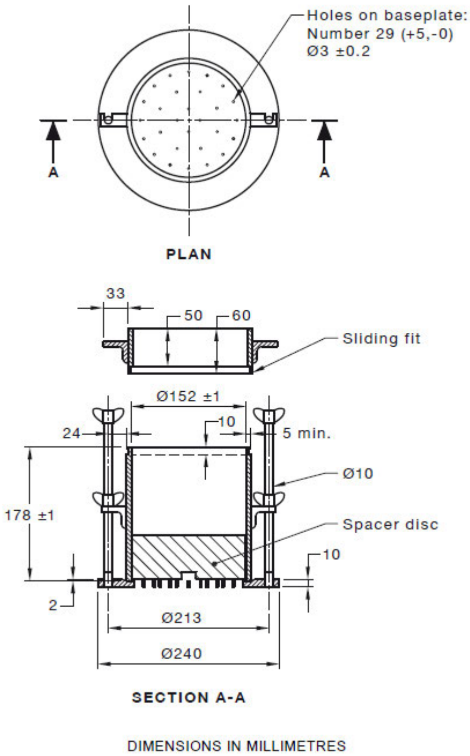

Figure 6 Schematic of CBR mould

Figure 7 Mechanical CBR at USQ

3.3 Data collection.

Samples from both RSA and Tierney's quarries near Dalby have been obtained. All information from testing from these samples will be collected and analysed.

Within this study there are many variables. To try minimising the impact these have on the results, multiple tests were carried out. This report uses the OMC of the samples supplied given by the quarry. Several tests can be performed at different moisture and powder contents. Moisture readings will be determined for each sample tested at various powder concentrations, and the resulting CBR graph can provide an answer.

3.4 TMR UCS comparison

According to the TMR specifications, achieving a target UCS of 1.5MPA requires adding cement powder at approximately 1.65% (Deptartment of Transport and Main Roads, 2022). This percentage will give a starting point for quantity powder to add to gain the optimal result in relation to the CBR test.

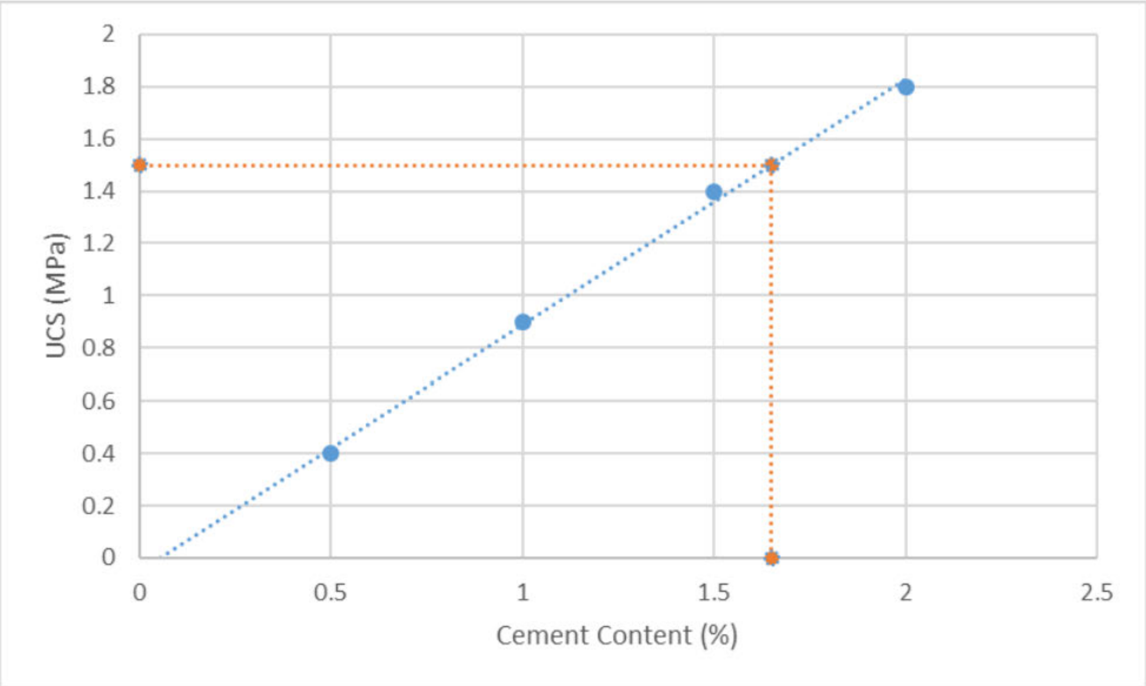

Figure 8 UCS vs Cement powder quantities (Deptartment of Transport and Main Roads, 2022).

As the TMR value of 1.65% additive has been determined and the traffic volumes of the studied roads are relatively low, the quantity of added cement during testing will range from a control of 0% stepping up a half a percent until 2.5% is reached.

3.5 Sampling.

Obtaining results will need to be carried out on a trial-and-error basis. This problem has two variables, moisture, and the quantity of added cement. One variable, the cement powder can be controlled but this will affect the moisture in the sample. This necessitates multiple tests to be carried out.

The variation in moisture is harder to control. Base OMC can be determined but as the quantity of powder changes the OMC of the sample may change due to hydration. The testing of each sample at differing moisture content will allow a determination.

4 Determinations.

For each sample tested the following is to be calculated then reported in accordance with test number Q113A in the MTM from TMR and the relevant Australian Standards (Deptartment of Transport and Main Roads, 2022) .

1. Insitu Moisture content.
2. The compacted moisture content.
3. Compacted dry density.
4. Air voids line (optional).
5. Californian bearing ratio at 2.5mm.
6. Californian bearing ratio at 5mm.
7. Compacted dry density versus compacted moisture.
8. Compacted dry density versus compacted moisture with zero air voids line.
9. A graph in semi-logarithmic bearing ratio compared to compacted moisture content.

4.1 Calculations.

Several calculations need to be carried out on each sample.

4.1.1 Moisture content.

Moisture content is be reported as a percentage. To get this information the sample is weighed in the natural state, with moisture. It is then dried in an oven for 16 to 24 hours with capacity of maintaining a temperature of 105-110C for this time .

$$w = \frac{m_b - m_c}{m_c - m_a} \times 100 \quad (1)$$

Where:

w = moisture content of soil, in percent

m_b = mass of container and wet soil, in grams

m_c = mass of container and dry soil, in grams

m_a = mass of container, in grams

4.1.2 The compacted moisture content.

The equation below can be used to determine the variation between OMC and moisture content while compaction is happening (Deptartment of Transport and Main Roads, 2022):

$$w_v = OMC - w_1 \quad (2)$$

Where:

$$w_v = moisture\ content\ variation\ between\ OMC$$
$$and\ moisture\ content\ during\ compaction, as\ a\ percentage.$$
$$w_1 = Moisture\ content\ of\ soil\ durring\ compaction, as\ a\ percentage$$
$$OMC = optimum\ moisture\ content\ of\ soil\ as\ a\ percentage.$$

4.1.3 Compacted dry density.

To get the dry density the following calculations were conducted (Deptartment of Transport and Main Roads, 2022):

$$\rho_d = \frac{100(m_2 - m_1)}{V(100 + w_a)} \quad (3)$$

Where:

$$\rho_d = compacted\ dry\ density\ (t/m^3)$$
$$m_2 = mass\ of\ mould, baseplate\ and\ compacted\ matertial\ (g)$$
$$m_1 = Mass\ of\ mould\ and\ baseplate\ (g)$$
$$V = effective\ volume\ of\ mould\ (cm^3)$$

$w = compacted\ moisture\ content\ (\%)$

4.1.4 Air voids line.

This line shows the relationship between the dry density and moisture content.

$$\rho_d = \frac{\rho_w \left(1 - \frac{V_a}{100}\right)}{\frac{\rho_w}{\rho_s} + \frac{w}{100}} \tag{4}$$

Where:

ρ_d = Dry Density of the soil in grams per cubic centimeter

ρ_w = density of water, in grams per cubic centimeter

V_a = Volume of air voids in the soil, expresses as a percentage of the gross volume of undried material

ρ_s = Soil partical density, in grasms per cubic centimeter

w = moisture content, expressed as a percentage of the mass of the dry soil.

4.1.5 Californian bearing ratio at 2.5mm.

Calculate the CBR value at 2.5mm (Deptartment of Transport and Main Roads, 2022):

$$CBR_{2.5mm} = \frac{100 \times P_{2.5}}{13.20} \tag{5}$$

Where:

$CBR_{2.5mm} = californian\ bearing\ ratio\ at\ 2.5mm\ penetration$
$P_{2.5} = pressure\ recorded\ at\ 2.5mm\ penetration$

4.1.6 Californian bearing ratio at 5mm.

Calculate the CBR value at 5mm. (Deptartment of Transport and Main Roads, 2022):

$$CBR_{5.0mm} = \frac{100 \times P_{5.0}}{19.8} \quad (6)$$

Where:

$$CBR_{2.5mm} = californian\ bearing\ ratio\ at\ 2.5mm\ penetration$$
$$P_{2.5} = pressure\ recorded\ at\ 2.5mm\ penetration$$

4.2 Reported.

A series of graphs using Excel are to be produced,

4.2.1 A compacted dry density versus compacted moisture.

For each specimen, provide a tabulated record of the compacted moisture content, compacted dry density rounded to the nearest 0.01 t/m3, as well as the bearing ratio at 2.5 mm penetration and the bearing ratio at 5.0 mm penetration (Deptartment of Transport and Main Roads, 2022):

4.2.2 Compacted dry density versus compacted moisture with zero air voids line.

A plot depicting the relationship between compacted dry density and compacted moisture content is accompanied by a representation of the zero air voids line, or the assumed zero air voids line, on a graph. This air voids line is not necessary and will not be included with this report (Deptartment of Transport and Main Roads, 2022).

4.2.3 A graph with bearing ratio compared to compacted moisture content.

A graph of bearing ratio on a semi-logarithmic scale versus compacted moisture content on a linear scale (UniSQ, 2021). When read the load value from the graph the CBR values can be calculated using equation (*5*) and (*6*). As we have determined CBR5.0 will be used as the final values. For clarity on the graph CBR2.5 will not be shown.

5 Discussion and results obtained.

Multiple results from the CBR testing carried at the UniSQ engineering laboratory described in the above will be presented here. The optimum quantity of powder required to enhance both the economic benefits and the longevity of a flexible pavement during rehabilitation work, in terms of CBR results, will be shown. A comparison between the results of the TMR work on the UCS test, shown in Figure 1, and results gathered here.

A direct comparison between the RSA quarry results and the results from this study cannot be drawn. This is study tests were carried out in an unsoaked condition and RSA were obtained after soaking.

5.1 OMC

The initial objective was to determine the OMC of the material. To find this, numerous moisture tests were carried out, and a graph illustrating the relationship between the dry density and moisture content was generated while varying the cement amounts. The OMC is determined by identifying the peak of the charts in Figure 9.

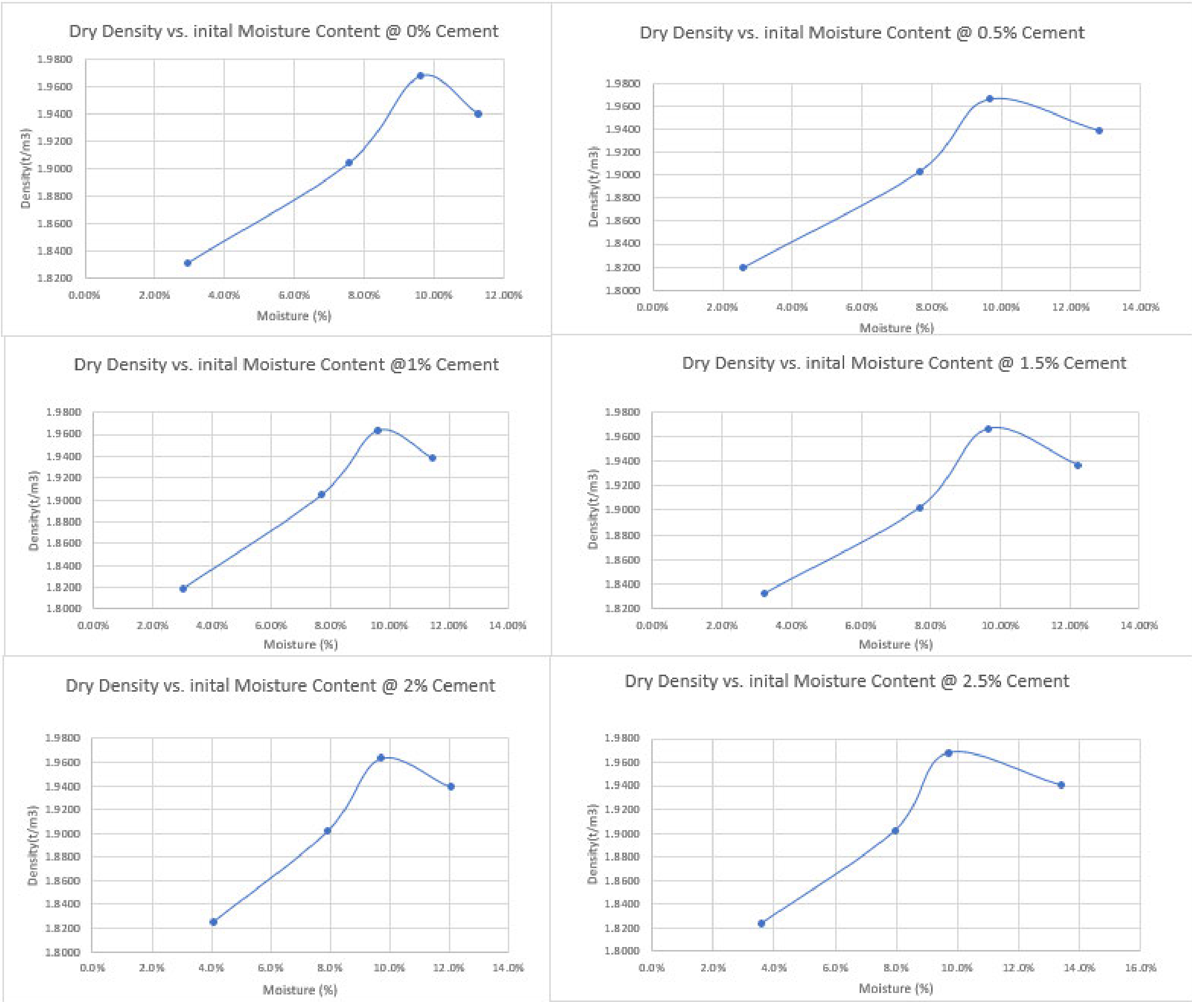

Figure 9 Dry Density vs Moisture.

A visual inspection of the graphs shown in shows the OMC to be 9.8%. This correlates with those obtained from RSA.

5.2 Load vs Displacement.

A graph with all different quantities of additive depicted showing load verses displacement has been produced. The CBR5.0 values can be obtained from this. Table 4 shows the visualised results against the calculated results.

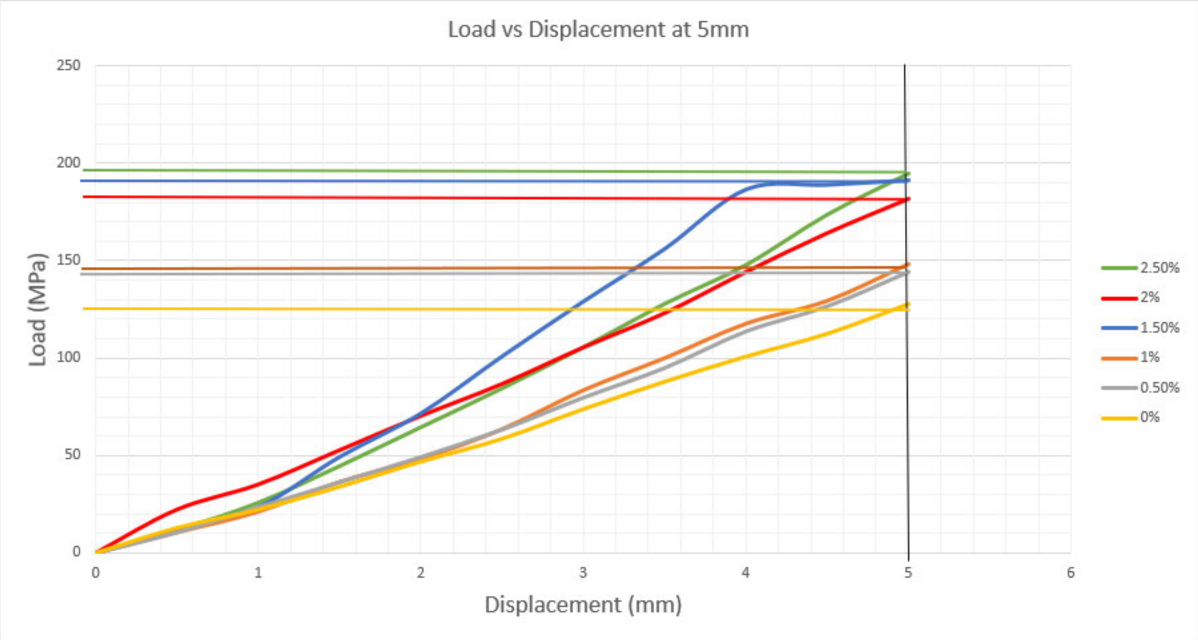

Table 4 Load vs Displacement.

5.3 Control or 0% cement added.

On first inspection the 5-millimetre CBR was producing a higher result. This is unusual and according to CIV3906 study book the CBR2.5 is usually higher (UniSQ, 2021). If this is not the case, as with this one, a second test to confirm the results is to be carried out. The quarry testing shown in figure 11 was studied and this was confirmed as correct.

The value of CBR5.0 at OMC read from Figure 10 is 132. This is higher than the quarry testing and can be put down to the difference in soaked and unsoaked testing.

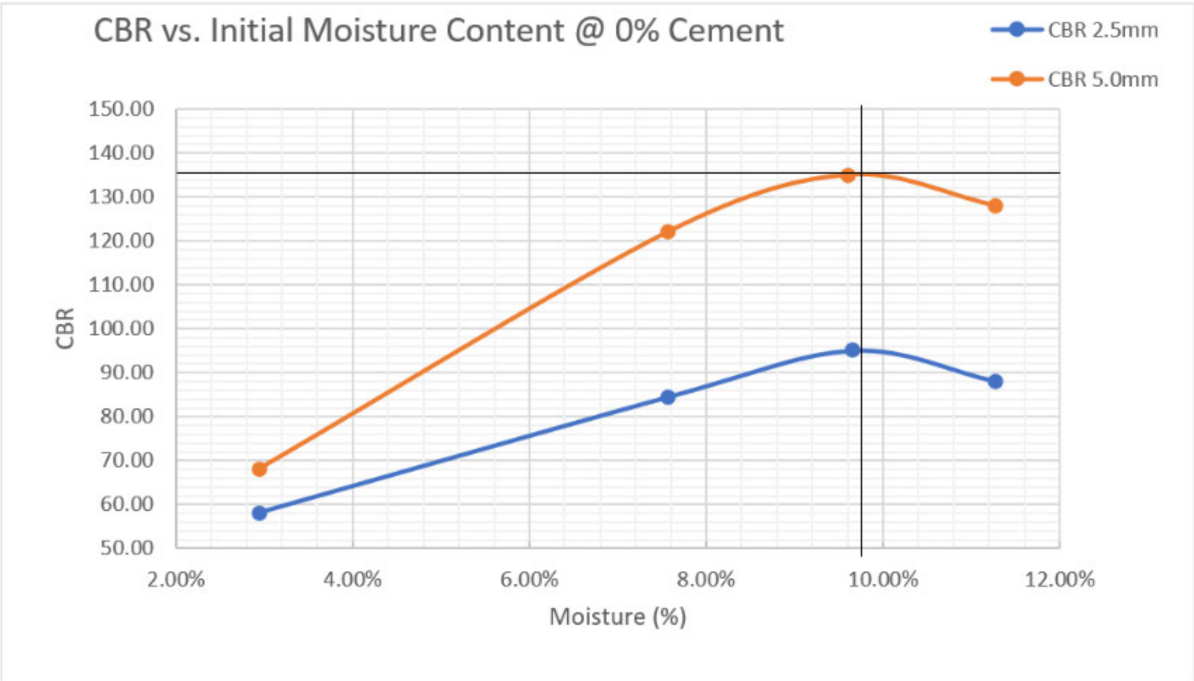

Figure 10 0% added cement.

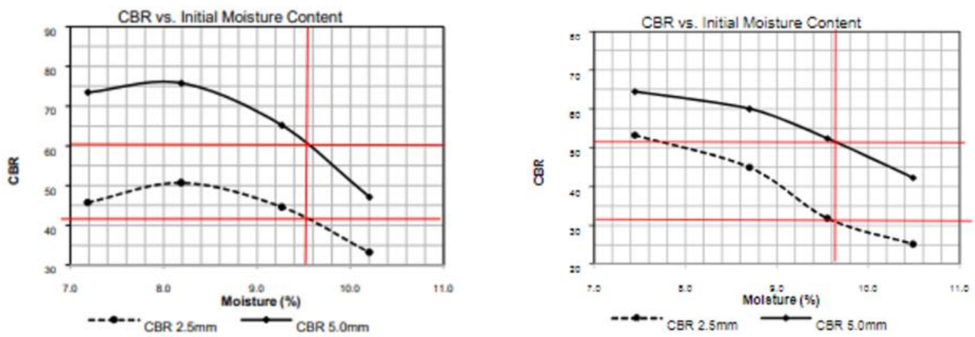

Figure 11 RSA Quarry confirmation (Lindsay, 2022).

5.4 0.5% cement added.

At 0.5% added cement the CBR5.0 at OMC is the higher again and when Figure 12 is considered a value of 212 was recorded.

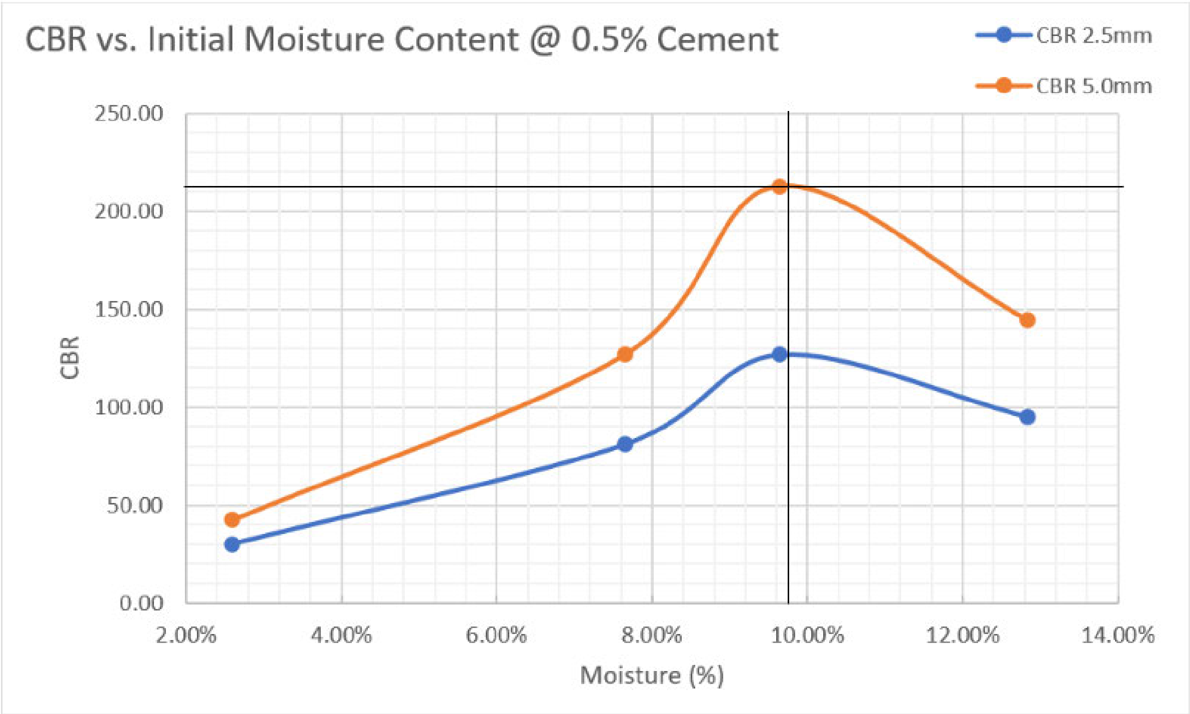

Figure 12 0.5% added cement.

5.5 1% added cement.

When 1% cement was added, the CBR5.0 at the OMC in Figure 13 has been documented as 180. This shows a sharp decline in values when the material has more than 8% moisture.

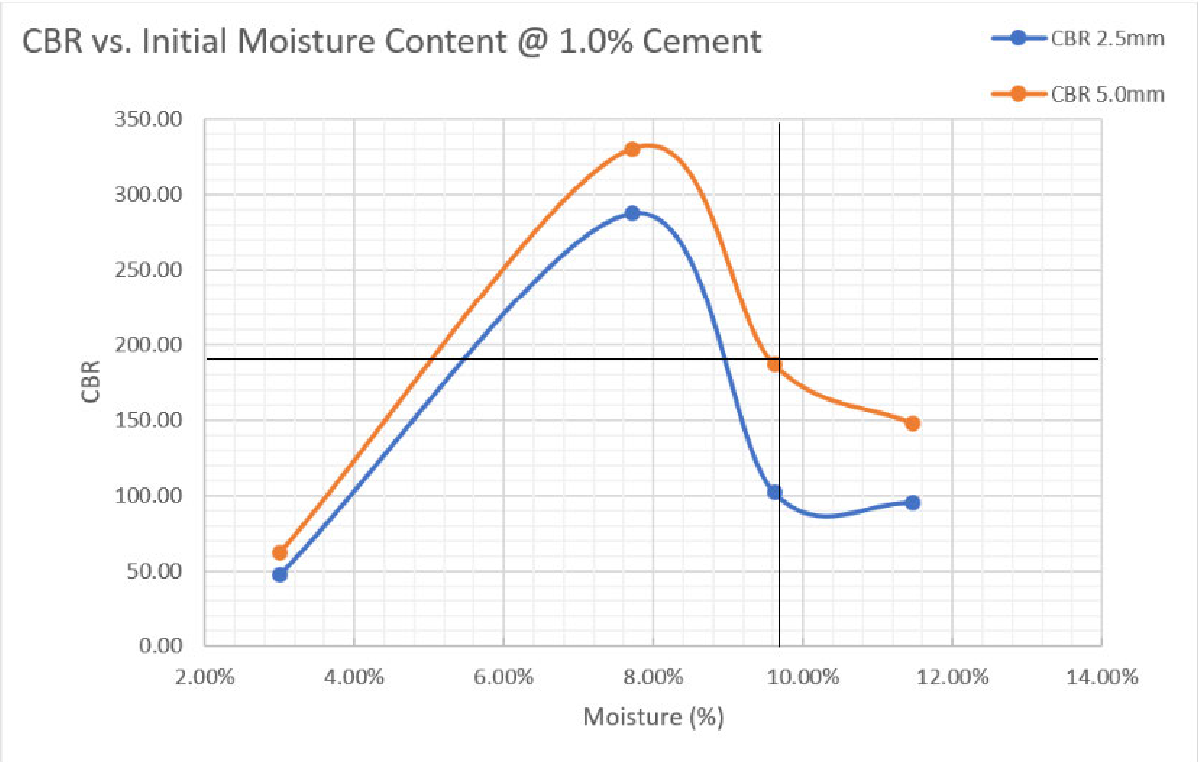

Figure 13 1% added cement.

5.6 1.5% added cement.

With 1.5% added cement, the CBR5.0 at the OMC in Figure 14 has been documented as 190. This also shows a sharp decline in values when the material has more than 8% moisture.

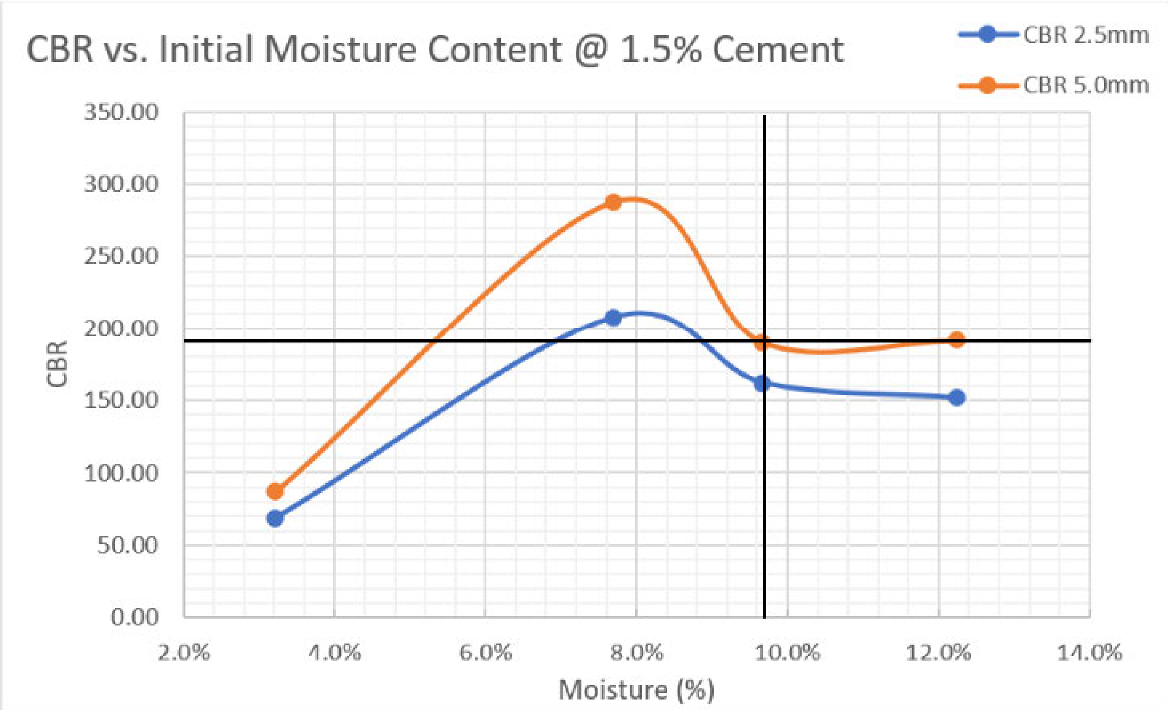

Figure 14 1.5% added cement.

5.7 2% added cement.

With 2% added cement, the CBR5.0 at the OMC in Figure 15 has been documented as 330. At this level of additive, it is noticed that the high point value is reached just before OMC.

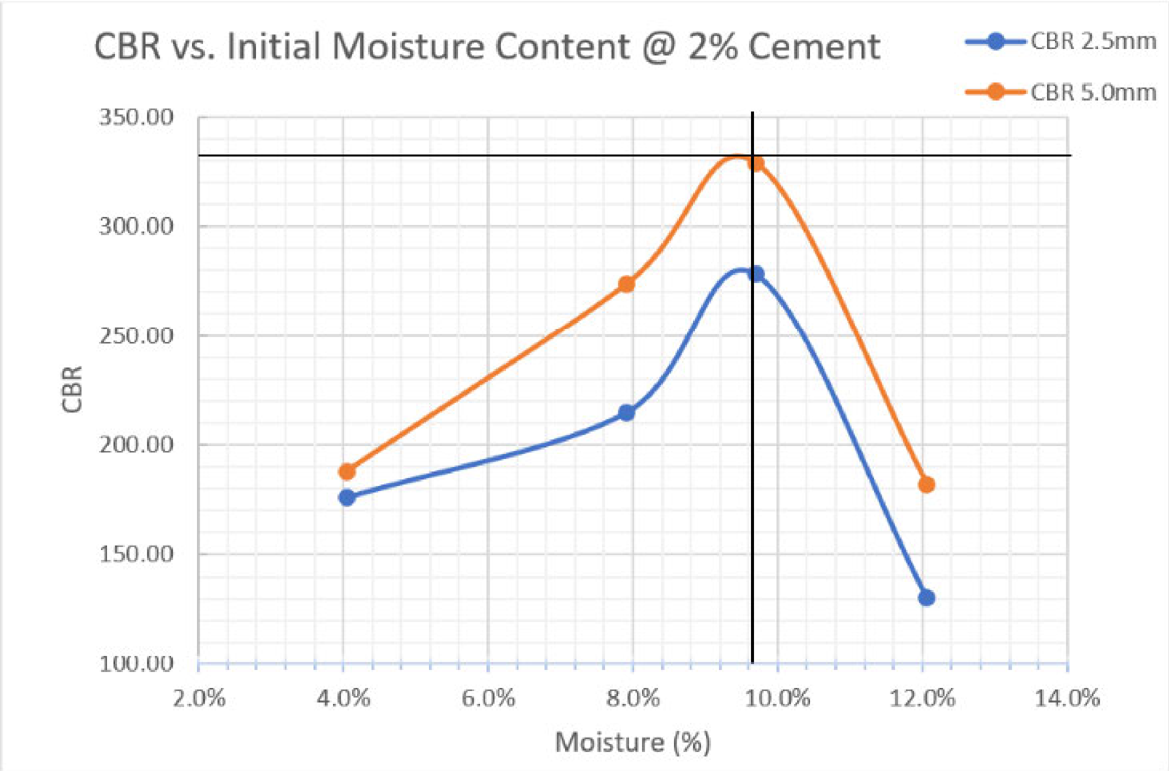

Figure 15 2% added cement.

5.8 2.5% added cement.

With 2.5% added cement, the CBR5.0 at the OMC in Figure 16 has been documented as 240. In this graph value decreases substantially before OMC is reached.

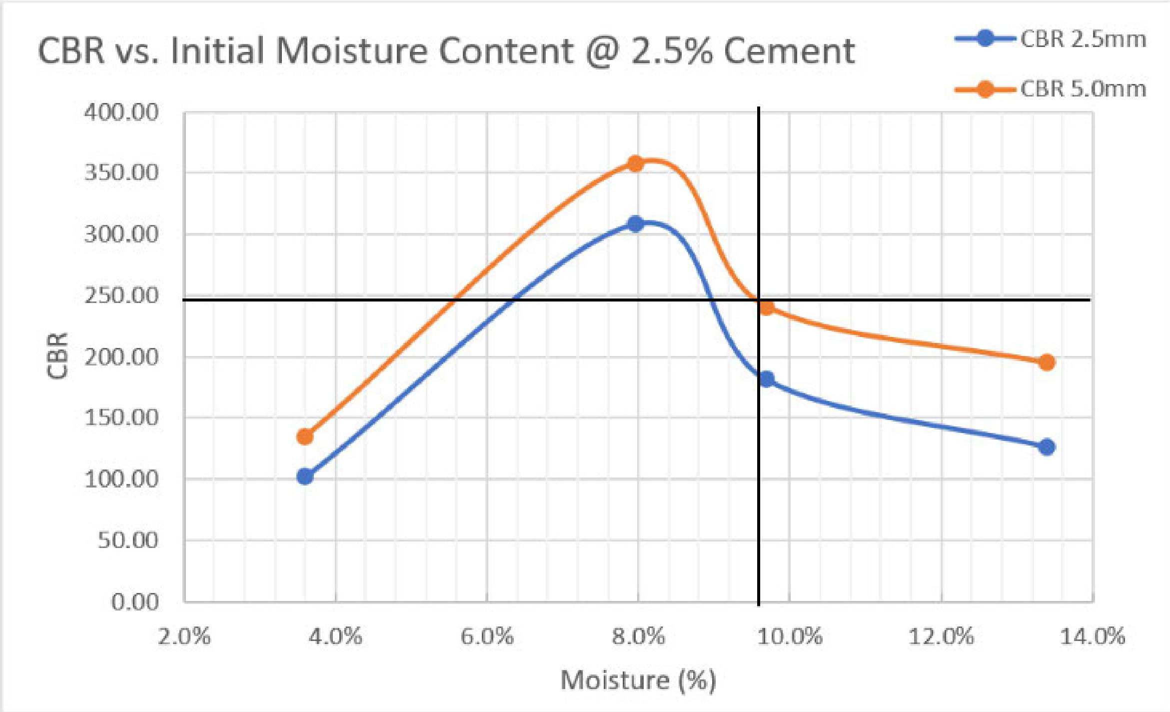

Figure 16 2.5% added cement.

5.9 Visual compared to calculated results.

Some time was spent comparing the results gathered from the graphs and the results that had been calculated using equation (*5*) and (*6*).

Table 5 Visual compared to calculated results.

Cement content	Visualised results from graphs	Calculated result.
0.0%	135	135
0.5%	225	213
1%	175	187
1.5%	190	190
2.0%	330	329
2.5%	245	241

There are only small differences in all results. It can be explained as human error in reading the graphs.

5.10 Discussion.

In the segment discussing the ideal strength, TMR has indicated that the addition of 1.65%, shown in green in Figure 17, cement powder will attain this goal.

When the results obtained in this study on CBR, shown in blue, and the previous TMR results regarding UCS testing it is noted that both studies have come up with similar answers.

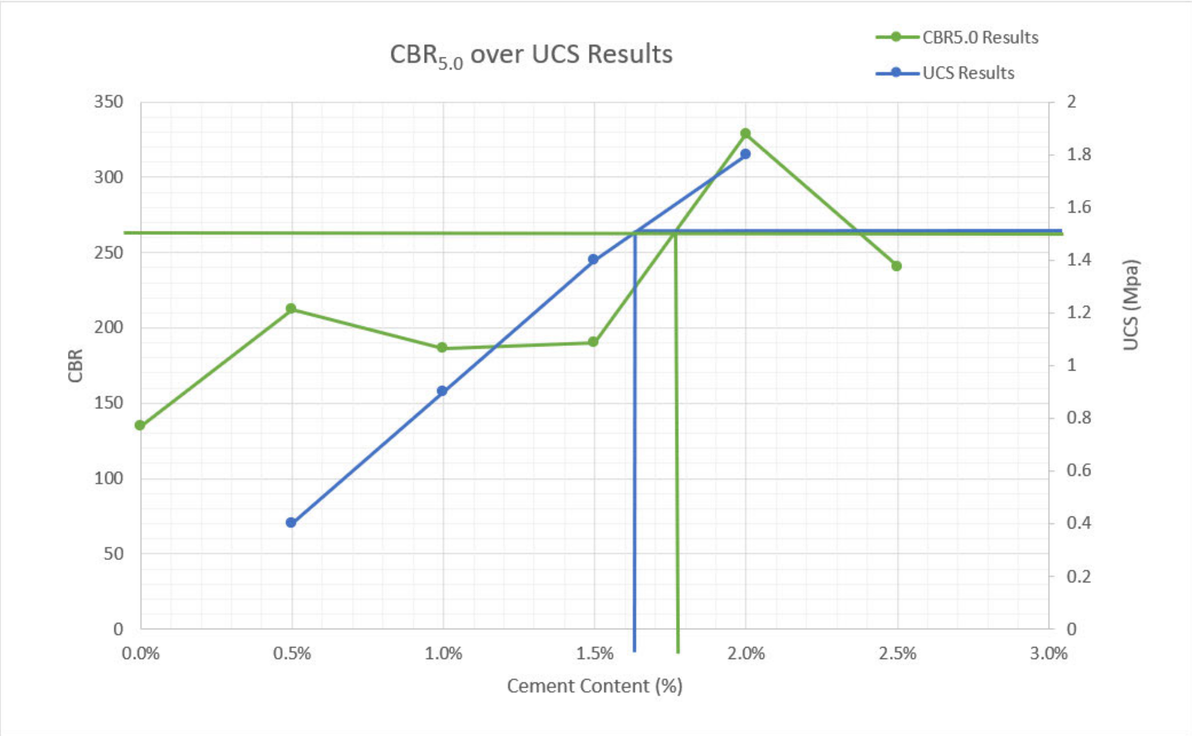

Figure 17 Overlay of CBR and UCS results.

In Figure 17, CBR testing, shown in green and TMR's UCS testing shown in blue, demonstrates that to achieve the recommended optimal UCS strength of 1.5MPA a percentage of 1.75% would be optimal. This is slightly higher than the quantity suggested by TMR.

6 Further Work.

During the preparation and literature review of this dissertation it had been identified that a limited amount of research had been carried out based on CBR testing. At the testing stage it was noted that to carry out this type of research it is difficult to manage the variables. With more time and experience as a laboratory technician, the issue of multiple variables could be reduced. A more accurate result may be gathered.

Time and resource constraints had limited the time to investigate any environmental cement powder. While completing this project other companies had produced and marketed an earth friendly or low carbon alternative to GP cement. A parallel study would be able to confirm or deny that using a low carbon powder has similar bearing capacity and therefore strength.

Another interesting suggestion would be to find if the higher bearing capacity subgrade other than what that is available on the Darling Downs would give different strength results than TMR had gained. Leading on from this the CBR testing regime could be applied.

Further on from the original suggestion the use of earth friendly cement to find if the strength out-comes are similar.

Finally, the use of organics as a stabilisation agent is interesting. There is a need for the academic community to reach consensus on the viability on this issue. The use of organics could reduce worldwide waste and could prove to be an earth friendly method of improving pavement layers if found effective.

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Appendix A - Project specifications

ENG4111/4112 Research Project

Project Specification

For: Richard Honan

Title: The effectiveness and sustainability of different cementitious blends have on pavement rehabilitation.

Major: Civil Engineering

Supervisors: David Thorpe

Enrollment: ENG4111 – EXT S1, 2023

ENG4112 – EXT S2, 2023

Project Aim: To find the optimum and most sustainable mixture of cement, flyash and lime combinations that are to be used on rehabilitation of roads in the Western Darling Downs area.

Programme: Version 3, 11th February 2023

1. Undertake background research to determine the level at which this topic has been covered previously. This will determine what level previous research that has been conducted.
2. Access Transport and Main Roads data and determine the extent their research on this topic. Some CBR testing at this point will be carried out to confirm results, if any, from TMR.
3. Develop a method of running a series of tests that can converted into a graph. The testing will both consider the sustainability and strength of the different combinations of the powder treatment.
4. Produce a budget which includes purchasing cement powder, flyash and lime. The University of Southern Queensland laboratory in Toowoomba will have the capability for all CBR test to be carried out.
5. Try and determine at what point the effect of reduced quantities of flyash reduce the strength of the road subgrade.
6. Earth friendly cement is a new product on the market. This product will be used in parallel testing and compared to standard GP cement.
7. Develop and analyse the results obtained.

If time and resources permit:

8. Some testing with differing quantities of lime in the powder mix
9. Find the point at which lime in the mix has a negative impact.

Appendix B - Report Risk Assessment.

1965	RISK DESCRIPTION	STATUS	TREND	CURRENT	RESIDUAL
	Dissertation report for ENG4111 & 4112.	Live		Medium	Not Assessed

RISK OWNER	RISK IDENTIFIED ON	LAST REVIEWED ON	NEXT SCHEDULED REVIEW
Richard Honan	11/02/2023		

RISK FACTOR(S)	EXISTING CONTROL(S)	CURRENT	PROPOSED CONTROL(S)	TREATMENT OWNER	DUE DATE	RESIDUAL
Working with equipment. Traveling to USQ and TMR laboratory. Office and computer work.	Control: As per USQ and TMR Safety protocols. When traveling be mindful of your surroundings and obey the law. —————— Control: When writing the report ensure regular breaks are taken.	Medium				

UniSQ

Risk Assessment [Ref Number: 1965]

Date Printed: Sunday, 5 March 2023

Name	Dissertation report for ENG4111 & 4112.	Current Rating	Residual Rating
Location	Toowoomba	Medium	
Business Unit		**Last Review Date**	**Risk Owner**
Faculty of Health, Engineering and Sciences			Richard Honan
Risk Assessment Team		**Risk Approver**	
David Thorpe		David Thorpe	
Additional Notes			
Describe task / use			
Producing a dissertation for an Honours degree. ENG4111 ENG4112			

Risk Factors

Risk Factor	Other

Description	
Working with equipment. Traveling to USQ and TMR laboratory. Office and computer work.	• -- --

Medium	
Existing Controls	**Proposed Controls**
• 6 - PPE: As per USQ and TMR Safety protocols. When traveling be mindful of your surroundings and obey the law. • 6 - PPE: When writing the report ensure regular breaks are taken.	

Appendix

Risk Matrix Level	
Very Low	Task can proceed upon approval of the risk assessment by the relevant supervisor, manager or higher delegate
Low	Task can proceed upon approval of the risk assessment by the relevant supervisor, manager or higher delegate
Medium	Task can proceed upon approval of the risk assessment by a Category 4 or higher delegate
High	Task can only proceed in extraordinary circumstances provided there is authorisation by the Vice Chancellor
Extreme	Task must not proceed. Appropriate and prompt action must be taken to reduce the risk to as low as reasonable practicable

Appendix C - Laboratory Risk Assessment.

NUMBER	RISK DESCRIPTION	TREND	CURRENT	RESIDUAL
2029	CBR testing-Z1		Low	Not Assessed

RISK OWNER	RISK IDENTIFIED ON	LAST REVIEWED ON	NEXT SCHEDULED REVIEW
Richard Honan	25/02/2023	25/02/2023	25/02/2024

RISK FACTOR(S)	EXISTING CONTROL(S)	PROPOSED CONTROL(S)	OWNER	DUE DATE
Lifting heavy items. Transporting materials needed for experiment. Strain can cause personal injury.	**Control:** Complete and follow compulsory induction. PPE. Use lifting equipment.	**Control:** eliminate any manual lifting above 20kg		25/02/2023
Using a slide hammer to prepare sample for testing. Mixing cement powder to sample causing dust.	**Control:** Use experienced personnel to train and monitor in the safe use of laboratory.	**Control:** Use PPE		25/02/2023

UniSQ

Risk Assessment [Ref Number: 2029]

Date Printed: Sunday, 5 March 2023

Name	**CBR testing-Z1**	**Current Rating**	**Residual Rating**
Location	**Toowoomba - Z1 Block, Level 1**	Low	
Business Unit		**Last Review Date**	**Risk Owner**
USQ Council		25/02/2023	Richard Honan
Risk Assessment Team		**Risk Approver**	
Wayne Crowell		David Thorpe	
Additional Notes			
Describe task / use			
Performing material testing in Z1 laboratory. Mixing 2.3 road-base to OMC and adding cement powder. Conduct CBR testing. To gain results for honors thesis. Course ENG4111 and ENG4112			

Risk Factors

Risk Factor	Ergonomics and Manual Handling

Description

Lifting heavy items. Transporting materials needed for experiment.
Strain can cause personal injury.

- Does the activity involve manual tasks: -- No
- Does the work involve:
- Awkward and unbalanced loads? -- Yes
- Bending and twisting? -- Yes
- Hand tool use? -- Yes
- Lifting, carrying and walking? -- Yes
- Repetitive movements? -- Yes
- Does the work involve sustaining static postures for long periods of time e.g. sitting or standing? -- No
- Are there egonomic hazards related to:

Low			
Existing Controls	**Proposed Controls**		
	Description	Responsibility	Target Date
• 5 - Administration: Complete and follow compulsory induction. PPE. Use lifting equipment.	eliminate any manual lifting above 20kg		25/02/2023

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Risk Assessment [Ref Number: 2029]

Date Printed: Sunday, 5 March 2023

Risk Factor	Mechanical and Fixed Plant

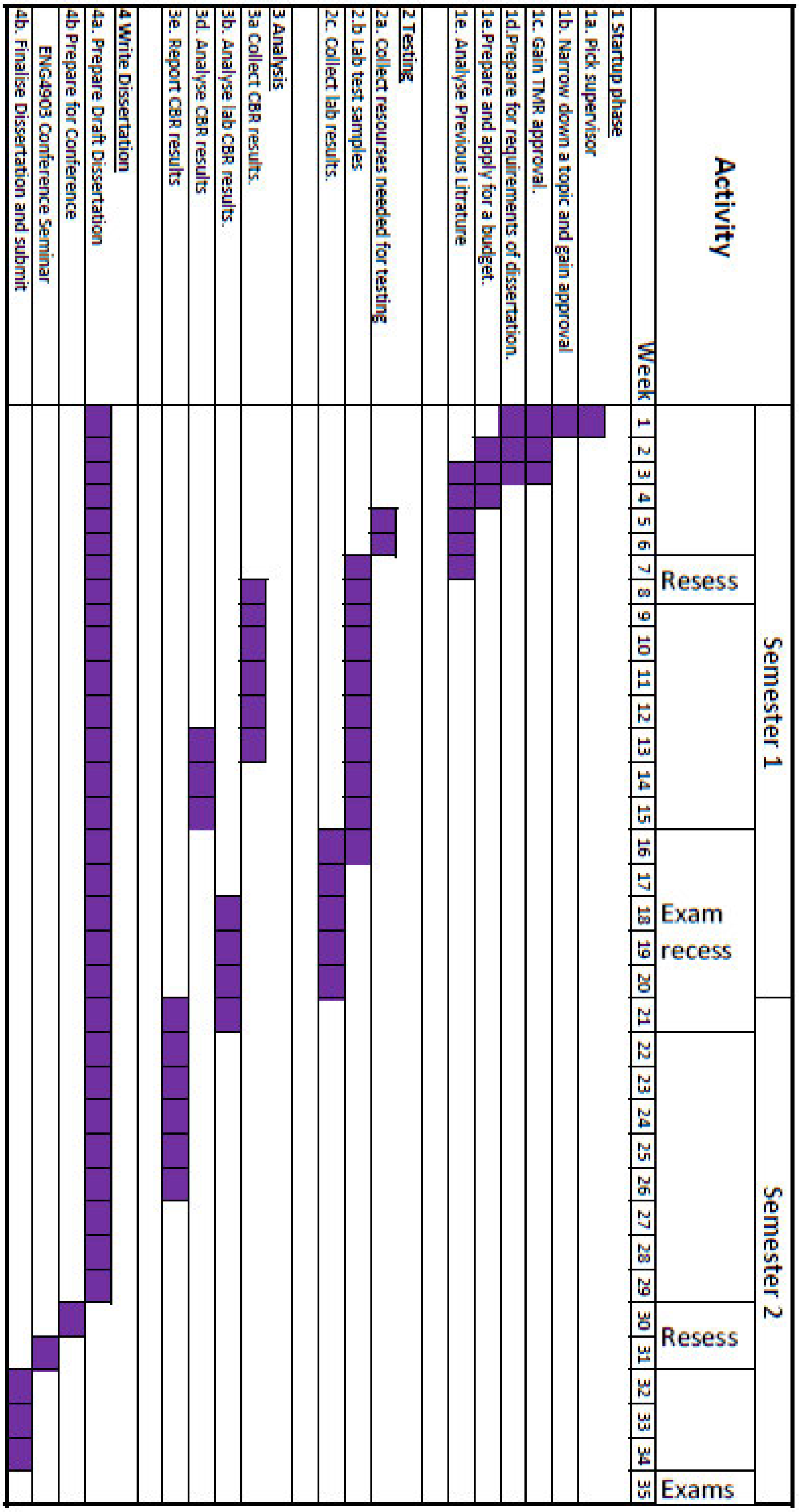
Description	
Using a slide hammer to prepare sample for testing. Mixing cement powder to sample causing dust.	• Is there the potential for: • Crushing and pinch points? -- Yes • Moving and rotating equipment? -- Yes • Could hazards be caused by equipment or structural failure? -- No

Existing Controls	Proposed Controls		
	Description	Responsibility	Target Date
• 5 - Administration: Use experienced personnel to train and monitor in the safe use of laboratory.	Use PPE		25/02/2023

Appendix

Risk Matrix Level	
Very Low	Task can proceed upon approval of the risk assessment by the relevant supervisor, manager or higher delegate
Low	Task can proceed upon approval of the risk assessment by the relevant supervisor, manager or higher delegate
Medium	Task can proceed upon approval of the risk assessment by a Category 4 or higher delegate
High	Task can only proceed in extraordinary circumstances provided there is authorisation by the Vice Chancellor
Extreme	Task must not proceed. Appropriate and prompt action must be taken to reduce the risk to as low as reasonable practicable

Appendix D - Project plan.



UniSQ calendar – Semesters 2023

University of Southern Queensland

2023

- Jan 01 | New Years Day
- Jan 02 | New Years Day– Public holiday
- Jan 09 | S1 Class registration opens
- Jan 26 | Australia Day – Public holiday
- Feb 13 | S1 Orientation
- Feb 20 | **S1 Study Period starts**
- Feb 24 | Last date to enrol - Bachelor of Nursing
- Mar 03 | **Last date to enrol & fee payment date (*)**
- Mar 17 | S1 Census date
- Mar 31 | Toowoomba Show holiday
- Apr 7 | Good Friday – Public holiday
- Apr 8 | Easter saturday – Public holiday
- Apr 9 | Easter Sunday – Public holiday
- Apr 10 | Easter Monday – Public holiday
- Apr 25 | Anzac Day – Public holiday

January 2023

SUN	MON	TUE	WED	THU	FRI	SAT
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

February 2023

SUN	MON	TUE	WED	THU	FRI	SAT
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28				

March 2023

SUN	MON	TUE	WED	THU	FRI	SAT
			1	2	3*	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24	25
26	27	28	29	30	31	

April 2023

SUN	MON	TUE	WED	THU	FRI	SAT
30						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29

May 2023

SUN	MON	TUE	WED	THU	FRI	SAT
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

June 2023

SUN	MON	TUE	WED	THU	FRI	SAT
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

July 2023

SUN	MON	TUE	WED	THU	FRI	SAT
30	31					1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21*	22
23	24	25	26	27	28	29

August 2023

SUN	MON	TUE	WED	THU	FRI	SAT
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

- May 1 | Labour Day
- May 19 | Ipswich Show holiday
- May 29 | S2 Class registration opens
- Jun 02 | **Academic withdrawal date**
- Jun 05 | Final Assessment Period starts
- Jun 16 | **S1 Study Period ends**
- Jun 28 | S1 Results released
- Jul 03 | S2 Orientation
- Jul 10 | **S2 Study Period starts**
- Jul 14 | Last date to enrol - Bachelor of Nursing
- Jul 21 | **Last date to enrol & fee payment date (*)**
- Aug 04 | S2 Census date
- Aug 16 | Ekka – Public holiday (Brisbane only)

Semester 1 Study Period Feb 20 – Jun 16	S1 key dates	Final Assessment Period	Flexible learning periods	
Semester 2 Study Period Jul 10 – Nov 03	S2 key dates	Public holidays	Apr 03 – Apr 14 Sep 18 – Sep 29 Dec 27 – Dec 29	
Semester 3 Study Period Nov 13 – Feb 09	S3 key dates	Census dates	S1 Study Break Jun 19 – Jul 07 S2 Study Break Nov 06 – Nov 10	

Contact iconnect | 1800 007 252 or 07 4631 2285
usq.support@usq.edu.au

UniSQ calendar – Semesters 2023

University of Southern Queensland

- Oct 2 | King's Birthday – Public holiday
- Oct 5 | S3 Class registration opens
- Oct 20 | **Academic withdrawal date**
- Oct 23 | Final Assessment Period starts
- Nov 03 | S2 Study Period ends
- Nov 06 | S3 Orientation
- Nov 13 | **S3 Study Period starts**
- Nov 15 | S2 Results released
- Nov 17 | Last date to enrol - Bachelor of Nursing
- **Nov 24** | **Last date to enrol & fee payment date (*)**

September 2023

SUN	MON	TUE	WED	THU	FRI	SAT
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

October 2023

SUN	MON	TUE	WED	THU	FRI	SAT
1	2	3	4	5	6	7
8	9	10	11	12	13	14
15	16	17	18	19	20	21
22	23	24	25	26	27	28
29	30	31				

November 2023

SUN	MON	TUE	WED	THU	FRI	SAT
			1	2	3	4
5	6	7	8	9	10	11
12	13	14	15	16	17	18
19	20	21	22	23	24*	25
26	27	28	29	30		

December 2023

SUN	MON	TUE	WED	THU	FRI	SAT
31					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28	29	30

January 2024

SUN	MON	TUE	WED	THU	FRI	SAT
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

February 2024

SUN	MON	TUE	WED	THU	FRI	SAT
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29		

- Dec 08 | S3 Census date
- Dec 24 | Christmas Eve – Public holiday
- Dec 25 | Christmas Day – Public holiday
- Dec 26 | Boxing Day – Public holiday

2024

- Jan 01 | New Years Day
- Jan 02 | New Years Day– Public holiday
- Jan 26 | **Academic withdrawal date**
- Jan 26 | Australia Day – Public holiday
- Jan 29 | Final Assessment Period starts
- Feb 09 | **S3 Study Period ends**
- Feb 21 | S3 Results released

Semester 1 Study Period Jan 20 – Jun 16	S1 key dates	Final Assessment Period	Flexible learning periods	
Semester 2 Study Period Jul 10 – Nov 03	S2 key dates	Public holidays	Apr 03 – Apr 14 Sep 18 – Sep 29 Dec 27 – Dec 29	
Semester 3 Study Period Nov 13 – Feb 09	S3 key dates	Census dates	S1 Study Break Jun 19 – Jul 07 S2 Study Break Nov 06 – Nov 10	

Contact iconnect | 1800 007 252 or 07 4631 2285
usq.support@usq.edu.au

All effort has been made to ensure event dates are correct at time of printing, however please refer to UniSQ website for more current information. CRICOS: QLD 00244B NSW 02225M • TEQSA PRV12081 • 2103087

Appendix E - Project Resources.

Project Resources.

Required Resources	Quantity	Source of Resource	Cost
PC With Microsoft windows with word and excel	1 only	Personal, HIG and TMR work, and USQ computers	$0
Internet connection	35 weeks	Personal, HIG work, and USQ computers	$0
Road Base	50kg	RSA Quarry and Tierney Crushing and Transport	$0
Cement Powder	20kg	Hardware BMS	$15
Wagners Earth friendly cement	10kg	Wagners	$15
Travel to gather supplies and to USQ lab for testing	6	Personal vehicle	$50
Flyash	10kg	Hardware (Bunnings order)	$20
Hydrated Lime	10kg	Hardware (Bunnings order)	$20
Sundries, Printing, pens paper and binding	As needed	USQ Printing allowance	$0
		Total	$ 120

Appendix F - RSA Test results.

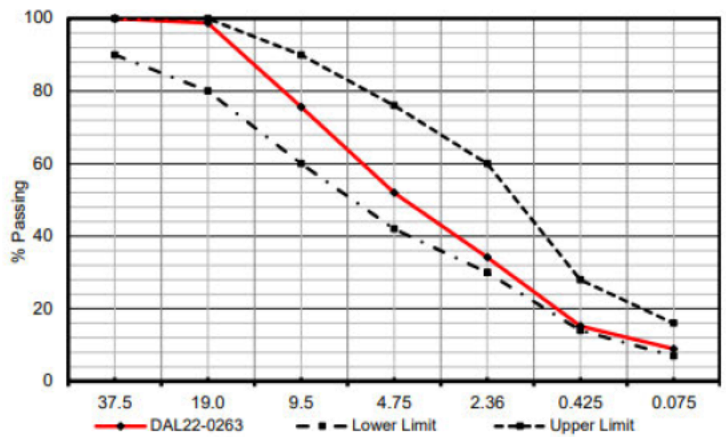
RSA CONSTRUCTION MATERIALS
ABN: 63 116 959 258 | Lot 290, Huston Road
PO Box 279, DALBY QLD 4405 | DALBY QLD 4405

Laboratory Contact
[redacted]

Test Report

MATERIAL SOURCE	**RSA Hustons Quarry**	REPORT NUMBER	**REP22-0263A**
PRODUCT	**Roadbase Subtype 2.3**	LAB REFERENCE NUMBER	**DAL22-0263**
LOT NUMBER	**HQ1241A**	PIT: BENCH: SHOT NUMBER	**Back:2**
TEST METHOD	**Q103A**	DATE TESTED	**10/10 - 18/10/2022**
SAMPLING METHOD	**Q050 8.2 Q060 8.1**	TESTED BY	**Paul Lindsay**
DATE SAMPLED	**6/10/2022**	SPECIFICATION	**MRTS05**
SAMPLED BY	**Darrin Cox**	CLIENT	**RSA Construction Materials**

A.S. SIEVE SIZE (mm)	Percentage Passing %	Lower Limit	Upper Limit
37.5	**100**	90	100
19.0	**99**	80	100
9.5	**76**	60	90
4.75	**52**	42	76
2.36	**34**	30	60
0.425	**15**	14	28
0.075	**8.9**	7	16



Other Tests	Method	Sample	Specified
Fines Ratio 0.075/0.425		**0.59**	
Liquid Limit %	Q104A	**29.2**	≤30
Linear Shrinkage %	Q106	**2.6**	1.5 - 4.5
Weighted Linear Shrinkage	Q106	**40**	≤110
Particle Density Water Absorptior	AS1141.6.1		≤3.5
Flakiness Index %	AS1141.15	**22**	≤40
CBR 5.0mm (Soaked)	Q113A	**60**	≥45

REMARKS	
CHECKED BY	**Paul Lindsay**
DATE REPORTED	**20/10/2022**
APPROVED SIGNATORY	[redacted]

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accredited for compliance with ISO/IEC 17025- Testing.
Accreditation Number: 17181

RSA CONSTRUCTION MATERIALS
ABN: 63 116 959 258
PO Box 279, DALBY QLD 4405

Lot 290, Huston Road
DALBY QLD 4405

Laboratory Contact
[redacted]

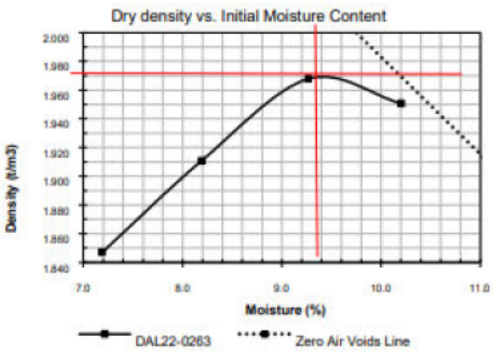
CALIFORNIA BEARING RATIO TEST REPORT

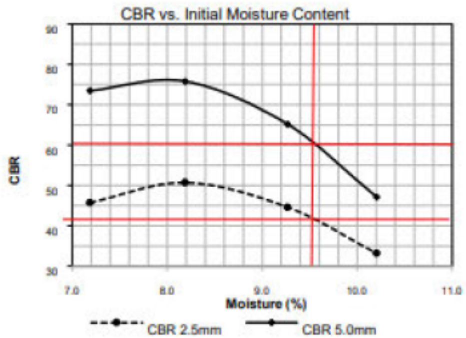
MATERIAL SOURCE	**RSA Hustons Quarry**	REPORT NUMBER	**REP22-0263B**
PRODUCT	**Roadbase Subtype 2.3**	LAB REFERENCE NUMBER	**DAL22-0263**
LOT NUMBER	**HQ1241A**	PIT: BENCH: SHOT NUMBER	**Back:2**
TEST METHOD	**Q113A**	DATE TESTED	**13/10 - 18/10/2022**
SAMPLING METHOD	**Q050 8.2 Q060 8.1**	TESTED BY	**Paul Lindsay**
DATE SAMPLED	**6/10/2022**	SPECIFICATION	**MRTS05**
SAMPLED BY	**Darrin Cox**	CLIENT	**RSA Construction Materials**

Tests Data

Initial Moisture Content (%) AS1289.2.1.1	Dry Density (t/m³)	CBR 2.5mm	CBR 5.0mm	Swell (%)	Final Moisture Content (%) AS1289.2.1.1
7.2	**1.847**	**46**	**73**	**0.1**	
8.2	**1.911**	**51**	**76**	**0.0**	
9.3	**1.968**	**45**	**65**	**0.0**	
10.2	**1.951**	**33**	**47**	**-0.1**	

Charts





Results Summary

CBR MDD (t/m³)	**1.970**
CBR OMC (%)	**9.4**
Test Condition	**Soaked**
CBR 2.5mm	**41**
CBR 5.0mm	**59**
Material CBR	**60**
Test Method	**Q113A**
Compactive Effort	**Standard**

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Accreditation Number: 17181

REMARKS		CHECKED BY	**Paul Lindsay**
APPROVED SIGNATORY	[redacted]	DATE REPORTED	**20/10/2022**

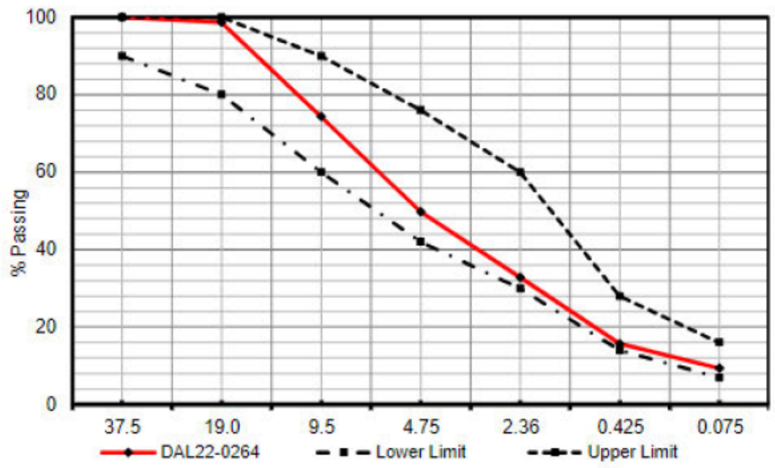
RSA CONSTRUCTION MATERIALS
ABN: 63 116 959 258 | Lot 290, Huston Road
PO Box 279, DALBY QLD 4405 | DALBY QLD 4405

Laboratory Contact
[redacted]

Test Report

MATERIAL SOURCE	**RSA Hustons Quarry**	REPORT NUMBER	**REP22-0264A**
PRODUCT	**Roadbase Subtype 2.3**	LAB REFERENCE NUMBER	**DAL22-0264**
LOT NUMBER	**HQ1241B**	PIT: BENCH: SHOT NUMBER	**Back:2**
TEST METHOD	**Q103A**	DATE TESTED	**10/10 - 12/10/2022**
SAMPLING METHOD	**Q050 8.2 Q060 8.1**	TESTED BY	**Paul Lindsay**
DATE SAMPLED	**6/10/2022**	SPECIFICATION	**MRTS05**
SAMPLED BY	**Darrin Cox**	CLIENT	**RSA Construction Materials**

A.S. SIEVE SIZE (mm)	Percentage Passing %	Lower Limit	Upper Limit
37.5	**100**	90	100
19.0	**99**	80	100
9.5	**74**	60	90
4.75	**50**	42	76
2.36	**33**	30	60
0.425	**16**	14	28
0.075	**9.3**	7	16



Other Tests	Method	Sample	Specified
Fines Ratio 0.075/0.425		**0.60**	
Liquid Limit %	Q104A	**29.6**	≤30
Linear Shrinkage %	Q106	**2.9**	1.5 - 4.5
Weighted Linear Shrinkage	Q106	**45**	≤110
Particle Density Water Absorptio	AS1141.6.1		≤3.5
Flakiness Index %	AS1141.15		≤40
CBR 5.0mm (Soaked)	Q113A		≥45

REMARKS	
CHECKED BY	**Paul Lindsay**
DATE REPORTED	**20/10/2022**
APPROVED SIGNATORY	[redacted]

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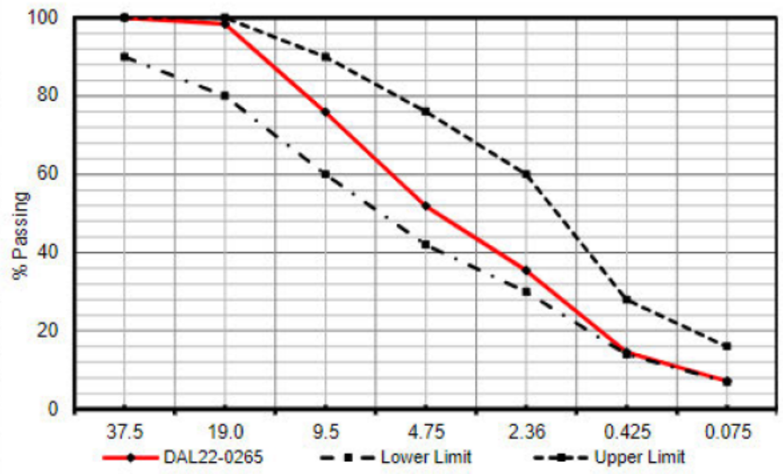
PO Box 279, DALBY QLD 4405 | DALBY QLD 4405

Laboratory Contact
[redacted]

Test Report

MATERIAL SOURCE	**RSA Hustons Quarry**	REPORT NUMBER	**REP22-01265A**
PRODUCT	**Roadbase Subtype 2.3**	LAB REFERENCE NUMBER	**DAL22-0265**
LOT NUMBER	**HQ1241C**	PIT: BENCH: SHOT NUMBER	**Back:2**
TEST METHOD	**Q103A**	DATE TESTED	**10/10 - 18/10/2022**
SAMPLING METHOD	**Q050 8.2 Q060 8.1**	TESTED BY	**Paul Lindsay**
DATE SAMPLED	**6/10/2022**	SPECIFICATION	**MRTS05**
SAMPLED BY	**Darrin Cox**	CLIENT	**RSA Construction Materials**

A.S. SIEVE SIZE (mm)	Percentage Passing %	Lower Limit	Upper Limit
37.5	**100**	90	100
19.0	**98**	80	100
9.5	**76**	60	90
4.75	**52**	42	76
2.36	**35**	30	60
0.425	**15**	14	28
0.075	**7.2**	7	16



Other Tests	Method	Sample	Specified
Fines Ratio 0.075/0.425		**0.49**	
Liquid Limit %	Q104A	**29.1**	≤30
Linear Shrinkage %	Q106	**3.0**	1.5 - 4.5
Weighted Linear Shrinkage	Q106	**44**	≤110
Particle Density Water Absorptior	AS1141.6.1		≤3.5
Flakiness Index %	AS1141.15	**23**	≤40
CBR 5.0mm (Soaked)	Q113A	**50**	≥45

REMARKS	
CHECKED BY	**Paul Lindsay**
DATE REPORTED	**20/10/2022**
APPROVED SIGNATORY	[redacted]

NATA ACCREDITED FOR TECHNICAL COMPETENCE

Accredited for compliance with ISO/IEC 17025- Testing.
Accreditation Number: 17181

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RSA CONSTRUCTION MATERIALS
ABN: 63 116 959 258
PO Box 279, DALBY QLD 4405

Lot 290, Huston Road
DALBY QLD 4405

Laboratory Contact
[redacted]

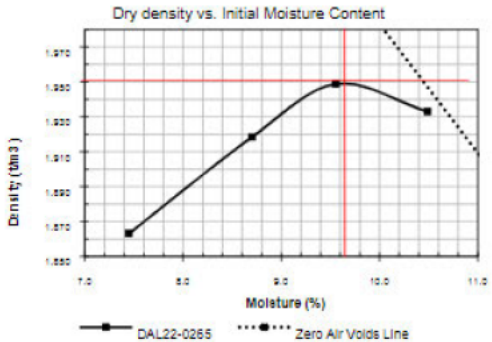
CALIFORNIA BEARING RATIO TEST REPORT

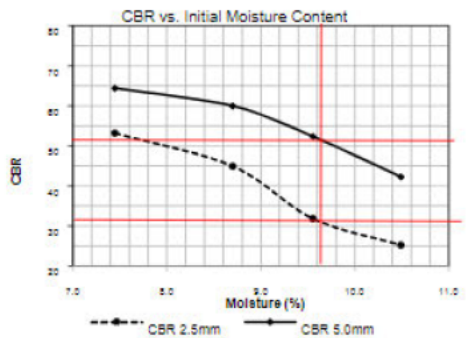
MATERIAL SOURCE	**RSA Hustons Quarry**	REPORT NUMBER	**REP22-0265B**
PRODUCT	**Roadbase Subtype 2.3**	LAB REFERENCE NUMBER	**DAL22-0265**
LOT NUMBER	**HQ1241C**	PIT: BENCH: SHOT NUMBER	**Back:2**
TEST METHOD	**Q113A**	DATE TESTED	**13/10 - 18/10/2022**
SAMPLING METHOD	**Q050 8.2 Q060 8.1**	TESTED BY	**Paul Lindsay**
DATE SAMPLED	**6/10/2022**	SPECIFICATION	**MRTS05**
SAMPLED BY	**Darrin Cox**	CLIENT	**RSA Construction Materials**

Tests Data

Initial Moisture Content (%) AS1289.2.1.1	Dry Density (t/m³)	CBR 2.5mm	CBR 5.0mm	Swell (%)	Final Moisture Content (%) AS1289.2.1.1
7.4	1.863	53	64	0.2	
8.7	1.918	45	60	-0.1	
9.6	1.949	32	52	0.0	
10.5	1.933	25	42	-0.1	

Charts





Results Summary

CBR MDD (t/m³)	**1.950**
CBR OMC (%)	**9.7**
Test Condition	**Soaked**
CBR 2.5mm	**31**
CBR 5.0mm	**51**
Material CBR	**50**
Test Method	**Q113A**
Compactive Effort	**Standard**
NATA ACCREDITED FOR TECHNICAL COMPETENCE	Accredited for compliance with ISO/IEC 17025- Testing Accreditation Number: 17181

REMARKS	***Soaking time 96 hours***	CHECKED BY	**Paul Lindsay**
APPROVED SIGNATORY	[redacted]	DATE REPORTED	**20/10/2023**

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RSA CONSTRUCTION MATERIALS

ABN: 63 116 959 258 | PO Box 279, DALBY QLD 4405

Lot 290, Huston Road | DALBY QLD 4405

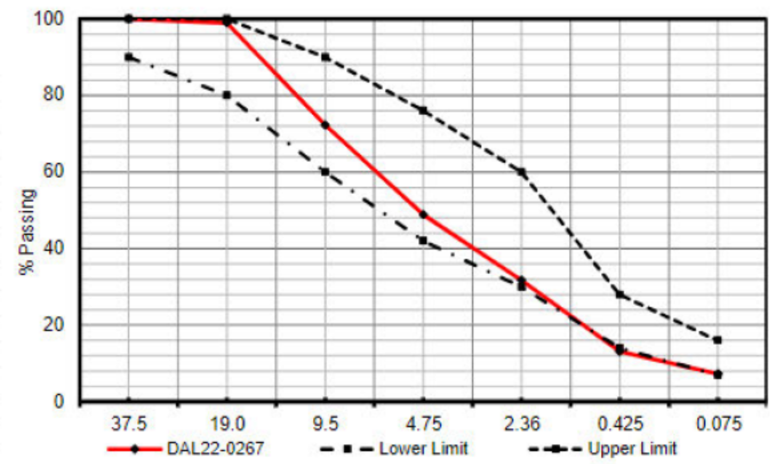
Laboratory Contact

[redacted]

Test Report

MATERIAL SOURCE	**RSA Hustons Quarry**	REPORT NUMBER	**REP22-0267A**
PRODUCT	**Roadbase Subtype 2.3**	LAB REFERENCE NUMBER	**DAL22-0267**
LOT NUMBER	**HQ1241E**	PIT: BENCH: SHOT NUMBER	**Back:2**
TEST METHOD	**Q103A**	DATE TESTED	**10/10 - 18/10/2022**
SAMPLING METHOD	**Q050 8.2 Q060 8.1**	TESTED BY	**Paul Lindsay**
DATE SAMPLED	**6/10/2022**	SPECIFICATION	**MRTS05**
SAMPLED BY	**Darrin Cox**	CLIENT	**RSA Construction Materials**

A.S. SIEVE SIZE (mm)	Percentage Passing %	Lower Limit	Upper Limit
37.5	**100**	90	100
19.0	**99**	80	100
9.5	**72**	60	90
4.75	**49**	42	76
2.36	**32**	30	60
0.425	**13**	14	28
0.075	**7.3**	7	16



Other Tests	Method	Sample	Specified
Fines Ratio 0.075/0.425		**0.56**	
Liquid Limit %	Q104A	**29.6**	≤30
Linear Shrinkage %	Q106	**3.0**	1.5 - 4.5
Weighted Linear Shrinkage	Q106	**40**	≤110
Particle Density Water Absorptio	AS1141.6.1		≤3.5
Flakiness Index %	AS1141.15		≤40
CBR 5.0mm (Soaked)	Q113A		≥45

REMARKS	
CHECKED BY	**Paul Lindsay**
DATE REPORTED	**20/10/2023**
APPROVED SIGNATORY	[redacted]

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Accreditation Number: 17181

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RSA CONSTRUCTION MATERIALS

ABN: 63 116 959 258 PO Box 279, DALBY QLD 4405
Lot 290, Huston Road DALBY QLD 4405

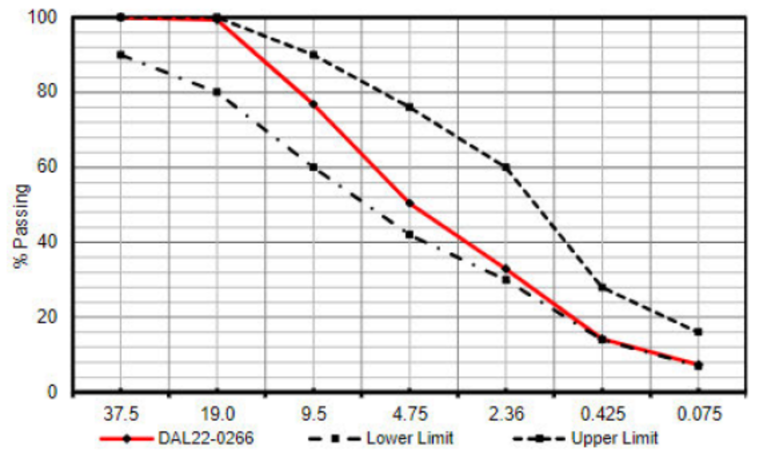
Laboratory Contact
[redacted]

Test Report

MATERIAL SOURCE	**RSA Hustons Quarry**	REPORT NUMBER	**REP22-0266A**
PRODUCT	**Roadbase Subtype 2.3**	LAB REFERENCE NUMBER	**DAL22-0266**
LOT NUMBER	**HQ1241D**	PIT: BENCH: SHOT NUMBER	**Back:2**
TEST METHOD	**Q103A**	DATE TESTED	**10/10 - 18/10/2022**
SAMPLING METHOD	**Q050 8.2 Q060 8.1**	TESTED BY	**Paul Lindsay**
DATE SAMPLED	**6/10/2022**	SPECIFICATION	**MRTS05**
SAMPLED BY	**Darrin Cox**	CLIENT	**RSA Construction Materials**

A.S. SIEVE SIZE (mm)	Percentage Passing %	Lower Limit	Upper Limit
37.5	**100**	90	100
19.0	**99**	80	100
9.5	**77**	60	90
4.75	**50**	42	76
2.36	**33**	30	60
0.425	**14**	14	28
0.075	**7.4**	7	16

Other Tests	Method	Sample	Specified
Fines Ratio 0.075/0.425		**0.52**	
Liquid Limit %	Q104A	**29.1**	≤30
Linear Shrinkage %	Q106	**2.8**	1.5 - 4.5
Weighted Linear Shrinkage	Q106	**40**	≤110
Particle Density Water Absorptio	AS1141.6.1	**2.3**	≤3.5
Flakiness Index %	AS1141.15		≤40
CBR 5.0mm (Soaked)	Q113A		≥45



REMARKS	
CHECKED BY	**Paul Lindsay**
DATE REPORTED	**20/10/2023**
APPROVED SIGNATORY	[redacted]

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