University Of Southern Queensland

Faculty of Engineering and Surveying

ALTERNATE PAVEMENT TYPES ON REACTIVE SOILS IN THE IPSWICH COUNCIL AREA

A dissertation submitted by

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in fulfilment of the requirements of

Courses ENG4111 and 4112 Research Project

towards the degree of

Bachelor of Engineering (Civil)

Submitted: October, 2009

Abstract

After seeing years of roadwork construction being done the same way and getting the same result of premature failures on the highly reactive subgrades in the Ipswich Council area, this author took the opportunity to research new technologies and innovations in road pavement construction.

The main objectives of this paper were:

- Investigate different pavement types used by Ipswich City Council (ICC).
- Determine how decisions are made regarding the gravel depth or use of lean mix / no fines concretes.
- Select a number of roads which have been constructed and analyse the success or failures of these roads.
- Investigate alternate technologies, innovative solutions and methods not previously used at ICC.
- Make recommendations on the costs and benefits of using the alternates.

Apart from the usual methods investigated like lime and cement stabilisation, the author found several different methods that could have significant impact on the performance of pavements in the Ipswich area:

- Foam bitumen stabilisation.
- Geosynthetics / Geogrids.
- Mass Foam blocks.
- Crushed glass in pavements.

Building road pavements on reactive subsoils is often a costly exercise and very easy to get wrong. New technologies have the ability to offer the same longevity and offer up to 30% savings over the traditional full depth gravel pavements.

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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.

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Signature

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Date

Acknowledgements

The author wishes to acknowledge the following people for their assistance in the compilation of this dissertation:

- Catherine Van De Poll – Project Engineer: Assistance with grammar checking, proof reading and formatting.

- Jon Freeman – Rehabilitation Manager, Ipswich City Council: Main source of information on the past history of pavements in the Council, including the supply of spreadsheets showing previous projects. Jon also gave assistance in the analysis of existing alternate pavement used within Council and supplied the Main Roads and Austroads manuals

- Josh Hutton – Contracts Engineer Ipswich City Council: Helped set up meetings with Brisbane City Council and provided the background information on the foam bitumen project on Redbank Plains Road.

- Associate Professor Ron Ayers: Project Supervisor providing guidance in the general direction of research that should be undertaken

Jeff Crone

University of Southern Queensland
October 2009

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Glossary

Bitumen Emulsion: Fine droplets of bitumen dispersed in water.

Blacksoil: A high plasticity clay, black in colour, very low bearing capacity.

C170 Seal: Class 170 bitumen sprayed seal.

CBR: California Bearing Ration, a common method of comparing soil strength.

Cement Treated Base: Gravel and cement powder mixed in a pugmill at the quarry before being placed as a pavement layer.

DG14 asphalt: Dense graded asphalt with the largest stone being 14mm.

GB Cement: General blended cement, can contain proportions of slag or fly ash.

Incorporated stabiliser: A large roadworks machine which excavates the pavement, pulverises, mixes the pavement with binder and water and places back on road.

Pavement: Layers of material, usually gravel, placed on the natural soil to support vehicle loads.

Stabilisation: A mechanical means of improving the in-situ pavement or subgrade.

Chapter 1 - Introduction

Ipswich City Council (ICC), like many others around Australia and indeed the world, has many of its roads founded on a highly reactive blacksoil clay with very low bearing capacity. Over the years various alternate pavement types have been trialled at ICC with varying degrees of success. Some of the trials are realising their full 20 year design life, where other trials have lasted only 3 years and have returned a very poor value for money ratio.

The aim of this paper is to investigate the previous trials undertaken at ICC and analyse them for their success or failure, making recommendations along the way. Not content with living in the past, the research for this paper stepped outside the bounds of ICC to look at what other Councils and State Departments in the area were doing and how the application of these alternate technologies would benefit ICC.

Once convinced that the savings and benefits of the alternates were real, the final step was taken into realistic on ground trials of an alternate technology and the resultant savings in time and budget would astound even the biggest critic.

Chapter 2 - Background and Literature Review

In order to understand the subject better, a review of Australian and International literature regarding reactive subgrades and alternate pavement types was undertaken.

The subject of reactive / swelling subgrade was well covered in available literature as the problem is not only endemic to Ipswich, but can be found in large proportions of Eastern Australia.

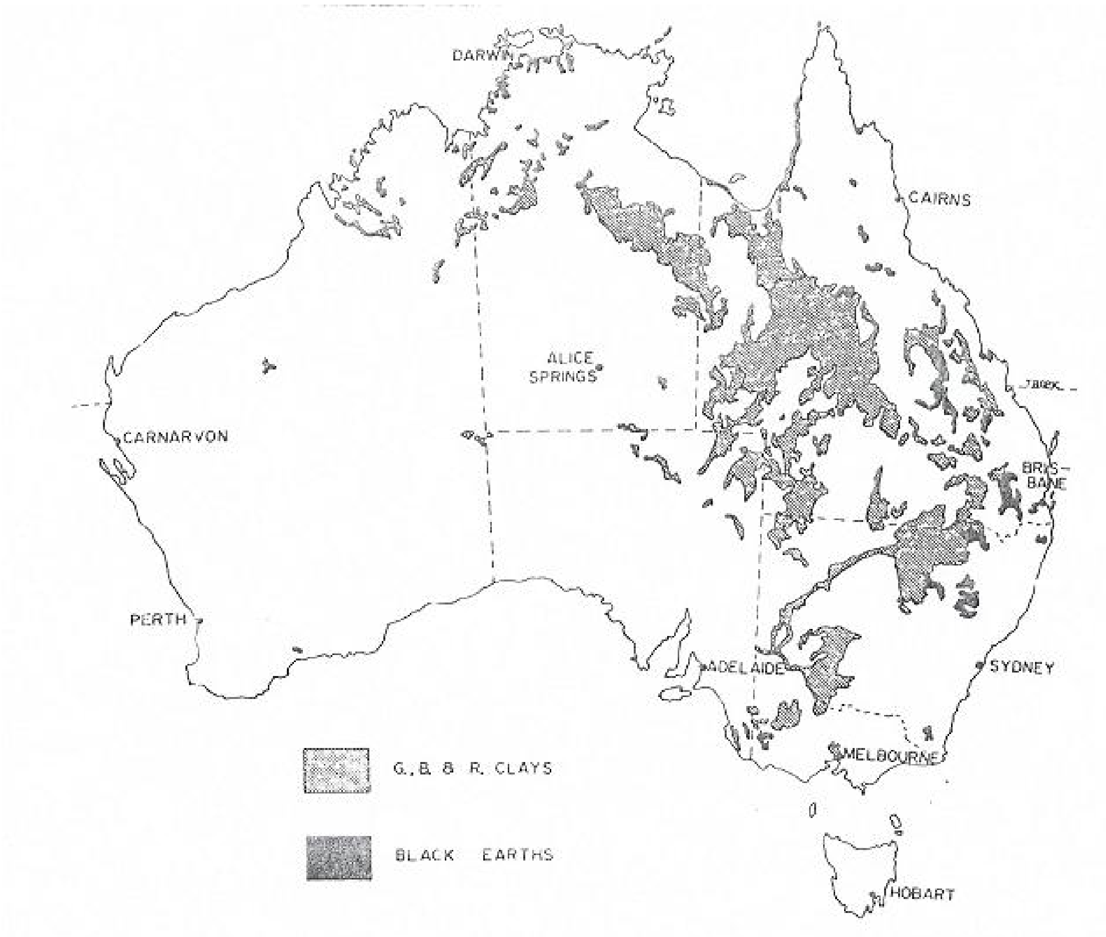

Figure 2.1: Extent of expansive clays in Australia. (Bradford 1978)

Bradford (1978) also indicates that there are many countries around the world with expansive soils : Canada, Ethiopia, India, Mexico, South Africa, Spain and USA. He also goes on to indicate that the estimated damage caused by swelling soils to building, roads, services etc in the USA in 1973 was $2,225 million dollars. So the problem is very real.

The available literature goes in to great detail to explain the various classes of clays which causes the swelling problem, however the one class of clay which causes the majority of problems in Ipswich is Montmorillonite.

Gamble (1973) took tests on the Montmorillonite clays in the Ipswich area and found the material to have the following properties.

Insitu Moisture Content	55 to 70 %
Liquid Limit	87 to 110%
Plasticity Limit	33 to 40 %
Plasticity Index	50 to 80 %
Liner Shrinkage	above 30 %

2.1 Dissertation from Cook

One of the more pertinent pieces of literature the was read, was a dissertation from Cook (2000) undertaken to fulfil the requirements of unit 70712 at the University of Southern Queensland.

His dissertation had a scope of investigating pavement performance in Wambo Shire in Southern Queensland, which suffers from the same reactive blacksoil that Ipswich does. The dissertation was centred on field trials and the results that followed from seven different pavement types on the Macalister Bell Road. The different pavement types are repeated here for clarity.

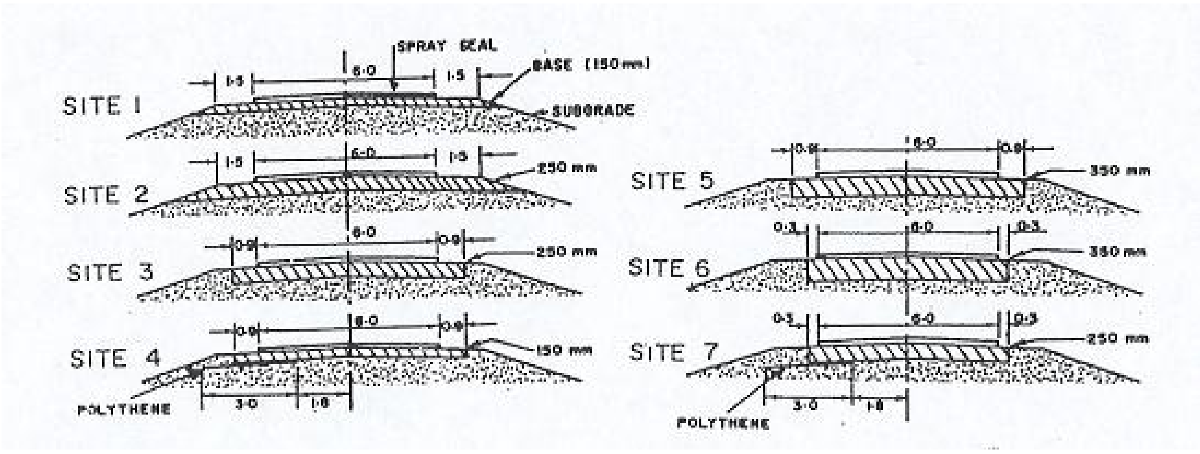

Figure 2.2: Pavement trials for the Macalister Bell Road. (Cook 2000)

This simple figure gave an immediate basis to see what has been trialled in other areas to combat the problem and also give alternatives to what is being done in this Ipswich area.

The paper goes on to briefly touch on lime and foam bitumen stabilisation, however this subject is covered better in other literature, so is left for now. The majority of Cook's (2000) paper investigates the success of the various trials, including maintenance schedules, graphs of rutting and degradation and swell testing. He concluded that no matter what the pavement trialled, the overriding factor is to control the moisture content in the edge of pavement subgrades. A thought which gave an added direction to the research being undertaken.

This dissertation was helpful, but was found to be extremely repetitive with very little information changing between the multiple trials and then the hundred pages of test data in the appendix seemed a little unnecessary.

2.2 Dissertation from Marangelli

Another dissertation found particularly useful was that of Marangelli (1973). Although this paper was significantly older, it shows that the problem has been around for a very long time and that we are still searching for answers to solve it.

This paper went into the technical side of why shrinking and swelling soils set up forces in the overlying pavement which eventually lead to: cracking of the pavement surface, infiltration of water into the pavement, reduction of bearing capacity, and finally break up of the pavement.

He summarised the stresses in the following sketch.

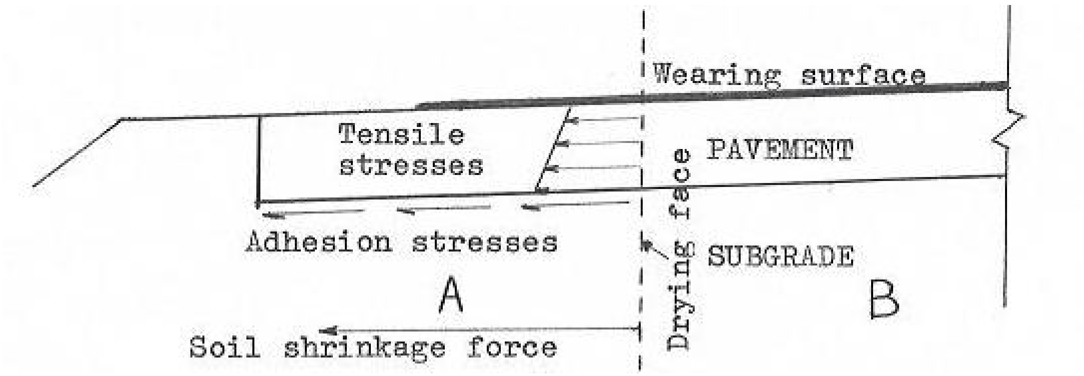

Figure 2.3: Stresses created on pavements from shrinking soils . (Marangelli 1973)

His paper went in to great detail at the various ways in which moisture can enter the pavement. He used a term not previously encountered, suction, referring to water being drawn into the dry sections of the pavement from the water table and the verges. This also gave a new direction to the research to be undertaken on how to control the moisture coming from below.

Marangelli (1973) theorised several ways on controlling moisture which are not currently used at Ipswich City Council including :

- Spraying a light seal on the subgrade to control the moisture gain or loss in the subgrade.
- Stage construction, allowing the subgrade to naturally approach equilibrium conditions before sealing (could be 12 months).
- Stabilising with cement
- Providing a waterproof membrane (plastic) under the shoulders.
- Full depth asphalt.

These theories gave direction of areas to be investigated for Ipswich. His paper was summarised with eight different methods to eliminate the effects of swelling soils.

1. Replacement – Remove altogether and replace.
2. Increase surcharge on subgrade – add more pavement layers
3. Compaction – compact subgrade at equilibrium moisture
4. Stabilisation
5. Pre wet subgrade before construction
6. Prevent moisture changes in subgrade
7. Improved cross section and drainage
8. Stage construction – leave subgrade open to achieve equilibrium moisture

2.3 Paper from Gamble

The most useful piece of literature found was a paper presented by Gamble (1978) to a seminar on foundations on expansive clay entitled "Design and construction techniques adopted by Ipswich City Council in the construction and maintenance of road pavements on expansive clay subgrades"

Bob Gamble was the deputy city engineer for Ipswich City Council at the time, and undertook an investigation to determine an economic way of constructing pavements on expansive clays as the existing pavements were realising high early maintenance costs. A situation that has not changed some 30 years later.

The extent of the clay problem in Ipswich is greater than most people realise. To quote Gamble (1973)

> *" … a band of Montmorillonite clay …. A minimum depth of approximately 15m and is known to be in excess of 100m in depth at some locations."*

He undertook eight different laboratory stabilisation tests with varying degrees of success.

1. Mechanical stabilisation with sand. He found that very large amount of sand were required for little improvement.
2. Mechanical stabilisation with coarse aggregate. It was found useful only for the low plasticity clays.
3. Stabilisation with Gypsum. No immediate conclusions could be drawn, however they believed the it will improve the CBR and moisture content.
4. Stabilisation with bitumen emulsion. Little improvement to properties, better as a waterproofing agent.
5. Stabilisation with fly ash. The readily available fly ash showed some improvement when used in large quantities, however construction practices prevented them using it in the field.
6. Stabilisation with cement. He found that the high in-situ moisture content of the Ipswich clays would require a mix of 8% by weight, which he surmised would lead to curing and shrinkage problems.
7. Stabilisation with Lime and Cement. More success was realised with using lime first to remove the moisture and increase the stability of the clay under construction machinery. Lime 3%, cement 2%.
8. Stabilisation with lime. He achieved optimal results with 5% lime.

His testing showed the lime stabilisation was the most beneficial for Ipswich City Council. He generally found that the best design for Ipswich pavements was:

Lime treated subgrade (5%)	150mm
Granular pavement	400mm
Asphalt surfacing	50mm

As a verification to this researcher that technology has changed significantly to explore new options, Gamble (1973) had problems with his workforce complaining about the effect of dust from the bagged lime. Today, specialist machines are used which rotovates the subgrade, pulverises the lumps into optimal size and includes lime internally before placing back onto the ground.

He also makes a good comparison between the costs of lime stabilisation at $1.60 per square metre and the equivalent in removing and replacing with gravel at $2.60 per metre. Whilst these costs are relative to the economics of 1973, it makes this researcher wonder why invaluable information like this, done in actual Ipswich conditions, is not compulsory reading for the designers and pavement engineers for projects in modern day Ipswich.

2.4 Research Report ARR190

Another invaluable source of information for this project was a research report by Heus (1990) entitled "Design and maintenance of residential streets". This innocuous title hides a gold mine of actual test sites in residential streets, including streets in Toowoomba Queensland, Fairfield and Blacktown New South Wales, Flinders and Collingwood in Victoria. However the real diamond find in this literature was a test site at Fox Street Booval, Ipswich.

Fox Street, reconstructed in mid 1986, is a local access road, upon which a 30m trial section was laid consisting of 50mm asphalt, 120mm of class 2 gravel and 80mm of class 3 gravel over the natural subgrade of CBR 8 medium strength clay.

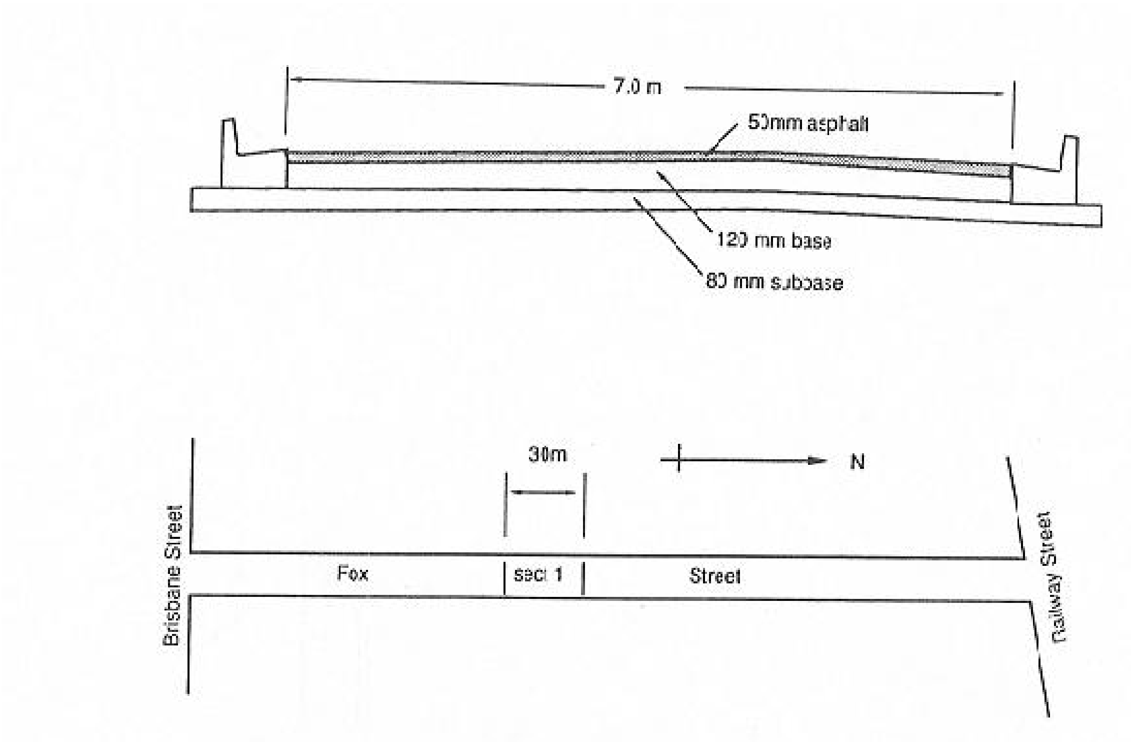

Figure 2.4: Trial pavement on Fox St Booval . (Heus 1990)

At the time, Fox Street had average daily traffic of 350 and design estimated standard axles (ESA) of 6.6 * 10^4, thus a pavement thickness of 250mm was taken from design curves.

Heus (1990) reports that a road condition survey undertaken in mid 1989 showed no problem with the pavement or the surfacing. A further survey in early 1990 showed a hairline longitudinal crack one metre from the kerb line. He indicates that this cracking is due to moisture changes (ingress) from the side which leads to differential movement in the subgrade.

Over the period that he tested the pavement, January 1987 to July 1988, the mean deflection in the pavement grew from 0.51mm to 0.59mm, which shows no significant change at the time. This section of pavement will form a pivotal part of the current investigations now that the initial trial is over 20 years old.

2.5 Other Literature

Various other sources of literature were studied, however as they relate better to the "Investigate possible alternate technologies, innovative solutions and methods" part of the project work, their usefulness and relevance to this project is only briefly summarised here.

- Polymer Composites II (Creese, Gangarao 2002) : indicates the usefulness of glass fibre polymer reinforced concrete overlays as used in California, Michigan, Ohio, Virginia and Washington.

- Thickness Design – Asphalt pavements for highways and streets (The Asphalt Institute 1981) : Explains the advantages of full depth asphalt pavements in the USA, including design charts in SI units.

- Australian adaptions and innovations in road and pavement engineering (Austroads 1995) : covers innovative practices in road construction including membrane treatments, foamed bitumen stabilisation and geotextile seals.

- Lime – fly ash – stabilised bases and subbases (transportation research board 1976) : A full lime – fly ash stabilisation analysis from chemical properties to construction practices in USA.

- Airport pavement innovations theory and practice (Hall 1993) : whilst not strictly related to road pavements, the literature reveals some innovative ideas to consider for use in roads.

- Guide to best practice for the construction of insitu stabilised pavement (Austroads 2003) : In booklet form, this will be useful in the direct comparison of Ipswich current practices.

Chapter 3 - Methodology: Finding the alternatives

While the literature research provided background information on the possibilities of alternatives, physical research involved interviews and meetings with other Councils and suppliers of alternate technology for physical proof and test results of any suggested alternatives. The following is a short record of the meetings that were held.

- 17/6/09, Meeting with David Craigie, manager of RPQ Civil. Initial discussions on the use of foam bitumen treatment. Outcome: the contractor outlined the foamed bitumen plant they possessed and the availability for Council projects.

- 30/7/09, Meeting with Raad Jarjees (Senior Manager, Project Construction – North) and Kevin Prandolini (Co-ordinator Project Construction – North) of Moreton Bay Regional Council (MBRC). A discussion was held on the problems faced by MRBC in constructing pavements on their heavy clay. Of particular interest is the use of Geogrids which is analysed further in chapter 7. Outcome: the realisation that MBRC faced similar problems to ICC, however, they had trialled alternatives that ICC were not using and found them successful.

- 31/7/09, Meeting with David Craigie (Manager RPQ Civil), Nicholas Rozis (Director, Bornhorst and Ward), Jon Freeman (Rehabilitation Manager ICC) and Paul Coker (Soil Lab Manager RPQ). Further discussion of the technical details of foam bitumen stabilisation and the benefits that are possible using the technology. Outcome: the realisation that neither the supplying contractor nor ICC had sufficient knowledge to use to trial this product within Council, as there were several important basic questions that could not be answered by the combined knowledge of the group. A secondary outcome of this meeting was a decision to approach the Main Roads experts for a combined training session.

- 4/8/09, Site visits with Jon Freeman (Rehabilitation Manager ICC). Many of the sites of the past 10 years of cement and lime stabilisation projects were visited and analysed for success or failure. Outcome: Photographs and notes were taken to aid in further analysis of the success of alternate pavement types constructed by Ipswich City Council.

- 6/8/09, Site visit with Dave McDonald (Operations Supervisor, Ellis Shoulder Paving Solution P/L). Looked at the various use of pavers and their interaction with alternate pavement types. Outcome: The paving machine had specific benefits that may be useful to Council in the future.

- 7/8/09, Presentation by Geofabrics Australia, Gary Tonks (Managing Director) and Kristina Schaeffer (Technical Manager). Formal presentation to a group of ICC project managers on the history and various uses of the Tensar Grid product. Outcome: A lot of interest from the group on the potential saving from use of the technology, however also skepitism for certain parts of the group that it was too good to be true and they did not believe the claims despite case studies going back over 17 years.

- 12/8/09, Meeting with Stabilised Pavements Australia, Darren Gearing (South Qld Manager) and Gavin Hocking (Operations Supervisor). This company is Councils annual supplier for stabilised pavement works. They indicated that their experience demonstrates cement additive should be limited to 3% to control cracking, which was contradictory to the proportion of additives Council had been using. Outcome: clarification from the stabilisation supplier that ICC were not using the same amount of additive that other Councils in the region were and could be an explanation for the premature failures that Council was realising.

- 17/8/09, Meeting with Josh Hutton (Contracts Engineer - Ipswich City Council) and Helen Bierton (Program Manager - Brisbane City Works). Discussion on the success of foam bitumen in the Brisbane Council area.

Outcome: verification that the pavement alternative was a realistic and cost effective option, if the conditions were suitable.

- 24/8/09, Meeting with Geofabrics Australia, Kristina Schaeffer (Technical Manager). Follow up meeting on how to use the provided software to analyse the savings due to the use of Geogrid. Outcome: Council now has the ability to analyse the predicted savings on any of their upcoming projects.

- 28/8/09, Formal training session with Main Roads, Jothi M Ramanujam (Principal Engineer – Pavement Rehabilitation). Formal session with a group of ICC Project Managers, that passed on the many secrets of Foam Bitumen Stabilisation that Main Roads have learnt since first trialling it in 1996. Outcome: verification of the success of the alternate pavement type, as well as a deeper understanding of the bounds and limitations that apply with its use.

- 29/8/09, Meeting with Logan City Council, Michael Pattison (Construction Manager) and Andre Retief (Program Coordinator). Discussion on the problems of pavement construction in Logan City Council and the methods they use to resolve them. Logan indicated their use of recycled concrete as an alternate pavement type that was working well in their area. Outcome: the realisation that Logan City Council faced similar problems as ICC, however, due to their city being younger, their requirement for rehabilitation of pavements was much lower.

Chapter 4 - Previous Pavements, successes and failures

Analysing the past 10 years of rehabilitation and new works, it was evident that Ipswich Council has tried various options to overcome the poor subgrade problems in the city. The fall back design position has always been to use full depth gravel pavement, which requires a substantial amount of subgrade replacement, so the depth of excavation easily can reach 700mm deep. Analysis of full depth gravel pavements will not be done in this paper, as this has been undertaken many times in professional documents, instead this research concentrates on alternate methods.

As noted in the background research, the Council has used several alternate methods of pavement construction, notably:

- Cement stabilisation of base and sub base layers
- Lime stabilisation of subgrades
- Use of lean mix concretes in both widening works and full width pavements
- Combination of both, lime in subgrade and cement in sub base
- Foam bitumen stabilisation

It is not the intention of this dissertation to explain the technical side of the processes and chemical reactions that occur to improve pavements, as this subject has been covered by many other papers, this chapter merely looks to analyse the success or failures of the treatments done to date. To date, generally foam bitumen stabilisation has not been attempted by day labour operations and is generally not well understood by Council, so analysis of foam bitumen options will be undertaken in chapter 7, alternate technologies.

4.1 Cement Stabilisation

In the past 10 years Council have performed approximately 50 cement stabilisation works. The full list of roads is attached in appendix B. Several of the projects were chosen and analysed for their success or failure. Councils initial approach to stabilisation was a 3% cement mix, however, after general blended (GB) cement became commonly available, Councils standard approach was a 4% GB cement mix on all jobs since 2001. This method of stabilisation using high cement additive has resulted in a fully bound Cement Treated Base (CTB) layer. The stiffness causes transverse cracks to develop.

4.1.1 Phillip Street Ebbw Vale

Phillip St is a short suburban street carrying a reasonable amount of traffic at 258 vehicles per day, as it feeds traffic from the main Brisbane Road into other residential streets behind it. It is in a very old section of Ipswich and typically has gas and water services at very shallow depths, which is why the decision to cement stabilise was taken, rather than a full depth gravel pavement. Also typical of the older sections of Ipswich, the original road was widened with a lean mix sub base to allow for kerb and channel. The problems with lean mix will be discussed in a later section, however as figure 4.1 shows, the problems with lean mix widenings are obvious.

Figure 4.1: Lean mix widening reflective cracking on Phillip St

The cement stabilisation works were undertaken in early 2001, which makes it about 8.5 years old at the time of the investigation. First inspected in 2004, no signs of cracking were evident, however, by January 2007, block cracking was occurring. Figure 4.2 reveals the extent of the cracking

Figure 4.2: Block cracking in Phillip St

An interesting point to note about Phillip St which may not be evident in the pictures is the crossfall to the kerb from the crown is between 4.5% and 5%, which is well above the designed 3% for this type of road. This problem is believed to be due to the inexperience of the day labour crew performing the works, they failed to take into account the bulking factor that occurs with stabilised pavements and the excess material was pushed up to the crown to maintain the existing kerb levels. Phillip Street was a 4% GB cement stabilisation of the top 150mm of base, followed by a prime and 2 coat seal of C170 bitumen. After less than 10 years, this road has failed and requires remedial work to the pavement layers to rectify.

4.1.2 Mary Street Blackstone

In stark contrast to Phillip St, Mary Street Blackstone, with 266 vehicles per day is in perfect condition for its age, despite being stabilised in 1998, some 3 years before Phillip St.

Figure 4.3: Mary St Blackstone – perfect condition for its age

The treatment for Mary Street was a 3% Cement stabilisation of the top 150mm of base followed by a prime and 2 coat C170 seal. It was monitored in 2004 and 2006 and no cracking or rutting was found. The differences noted was that Mary St had only 3% cement content in the stabilisation, and this research is indicating that this lower content has allowed the pavement to flex a little more and cracking is not occurring.

4.1.3 Redbank Plains Road, Redbank Plains

Redbank Plains Road is a very high traffic distributor road carrying approximately 14000 vehicles per day. It was treated with a 4% GB cement stabilisation of the top 175mm of base in late 2002 and is showing severe signs of distress with rutting and cracking evident. This time the road was sealed with a primerseal and 50mm DG14 asphalt, which seemed to become the standard from late 2001 onwards.

Figure 4.4: Bad rutting and cracking on Redbank Plains Road

The pictures show multiple sections of failure repairs which are again failing to the point where this section of road is in urgent need of further rehabilitation, noting that it is only 7 years old. Analysis of customer service complaints reveal that this road is one of the most complained about roads in the city by the travelling public. The research from this paper concludes that there is insufficient pavement depth to cater for the volume of traffic using this road, despite the use of cement stabilisation.

4.1.4 Brennan St Bellbird Park

At first glance, the reasoning behind Brennan Street having significant rutting was not obvious. The traffic count was 1687 vehicles per day, and while significantly more than Phillip or Mary Streets, it was nowhere near the volume of Redbank Plains Road. Brennan Street was a 4% GB cement stabilised of the top 150mm of base in late 2000, followed by prime and 2 coat seal. Originally inspected in 2004, it showed no signs of cracking, however now in 2009, while it still had no cracking, it showed significant rutting in the wheel paths that now need rectification.

Figure 4.5: rutting deformation on Brennan Street Bellbird Park.

It took a little further digging on the history of Brennan St to understand that in the past it was a significantly used shortcut between the two major distributors of Redbank Plains Road and Jones Road, however since the opening of new section of Jones Road extension, the traffic volumes dropped back to the reasonable levels we see today. The conclusion drawn from this information was that the stabilisation and seal coats were sufficient, however, once again, the excessive volume of traffic suggests the pavement depth is the problem.

4.1.5 Collector streets in Riverview

Rounding off the investigations into cement stabilisations, were a collection of streets in Riverview: Mitchell, Hayden and Price Streets. All were a 3% cement stabilisation of the top 200mm of gravel back in early 1999, and were followed with a prime and 2 coat seal. The job of investigating the streets was made a little more difficult as these streets were resealed mid 2008, however there was certainly no sign of rutting or cracking, and the historical data indicates no signs of cracking in 2004 and 2007. Once again, the research tends to indicate that the 3% mixture with bitumen seals was more successful, with 200mm of base being stabilised to cater for the 1444 vehicles per day on these streets.

4.2 Lime Stabilisation

As found during the literature review, Ipswich has a long history of lime stabilisation work due to the extensive blacksoil conditions found in most parts of the city. The earliest record of lime stabilisation occurred in 1961 with the majority of the streets being done in the mid to late 1970s, then no further treatments occurred until the mid 1990s. This large gap in lime works is reflected in interviews with many other Councils in the South East Queensland area where it fell from favour because of some high profile failures that occurred in the late 1970s. The last recorded list of streets that were treated with lime stabilisation has been included in appendix C. Several streets were investigated for the success of the treatment.

4.2.1 Madden Lane Rosewood

Madden Lane was a lime stabilisation project performed in 2001. The lane is notoriously flat with only 0.3% grade on the kerb and channel. The blacksoil in this area is typical of that which Gamble described in his paper, clays hundreds of metres thick. The pavement design consisted of a 6% lime stabilisation of the subgrade to be followed by 3 layers of gravel incorporating the kerb. Job records show that on the day of the stabilisation works the job was hit by an unexpected storm event and the boxed construction filled with water. Popular folklore in the area tells of how the local young aboriginal children delighted in going for a swim in their new swimming pool/road only to come out white from the lime. The water eventually dissipated and the lime was rotivated into the subgrade and the job proceeded as per plan.

Today, Madden Lane still serves 30 residential houses and a small side street, its condition is generally poor with significant longitudinal cracking and some large failure repair sections, especially alongside the kerb . The lack of any deformation along the kerb line and pavement in general tends to indicate that the stabilised subgrade is carrying the required load, so there must be another issue causing the cracking. Noting that the pavement width is 11 meters, reference to Austroads (2003) “Guide to best practice for the construction on insitu stabilised pavements” indicates that when 4 side by side passes of the stabiliser are required, such as in this case, that this should be done over 2 days otherwise excessive shrinkage occurs. This appears to be the case on Madden Lane and this problem will be explored with an upcoming investigation on Suffield Drive.

Figure 4.6: Madden Lane Rosewood longitudinal cracking

Figure 4.7: Madden Lane Rosewood failures and cracking

4.2.2 Bernadette Crescent Rosewood

Bernadette Crescent is within a kilometre of Madden Lane and shares the same very poor subgrade. It was a lime stabilisation project performed in 1998, 3 years earlier than Madden Street. Plans are no longer available for this pavement however it is understood it is a 6% lime stabilisation with 2 layers of gravel. The pavement in this case is extremely cracked and significant deformation is occurring in the pavement itself to the point where it is ponding water and the kerb is also shifting around. Bernadette Crescent is only a very narrow street at 5m lip to lip of kerb, so it is assumed the cracks are not due to lime shrinkage. Without first hand knowledge of the process involved, the only conclusion that can be drawn is that the stabilisation process was performed incorrectly, as the movement evident in the street can be directly attributed to subgrade failure.

Figure 4.8: Bernadette Cres Rosewood, kerb and pavement deformation, ponding water

Figure 4.9: Bernadette Cres Rosewood, cracking and kerb misalignment

4.2.3 Boscawan Crescent Bellbird Park.

The last project using lime stabilisation was Boscawan Cres, Bellbird Park. The stabilisation, performed in 2005, was a 5% quicklime mixed 200mm into the blacksoil subgrade, followed by 3 layers of gravel with the kerb and channel. An incorporated lime spreader was used on this job to rotivate the subgrade, mix in the lime and water and place back down, all inside the machine. The use of this particular machine was supposed to prevent the common lime dust problems that occur in residential areas. Despite the best efforts of Council in warning resident to put cars undercover, the lime dust spread over nearby houses and cars and Council had several cars detailed to remove the lime product.

Current analysis of Boscawan Cres show the pavement to be in perfect condition with no cracking or rutting evident in the majority of the pavement. There is a small section that is an exception, this is noted below in the lean mix analysis.

Figure 4.10: Boscawan Crescent in perfect condition

4.3 Lean mix pavements

Lean mix pavements have been the preferred option with Council for about the last 12 years. A lean mix pavement, as opposed to a full concrete pavement, is a mix of 4% GB cement, 20mm aggregate and few fines. The mix is delivered straight from an agitator truck and compacted with a vibrating plate to the required level. The placing of the product has significant advantages over gravel, especially in small (under 2m) road widenings where it is not possible to mix the gravel correctly with the machinery Council owns. Lean mix is also favoured over normal concrete layer as it is easier to excavate in the future if new services are required. It is for these reasons that it has had widespread use in a lot of Council work and seems to be the perfect pavement material if not for the significant drawbacks of cracking and rutting.

4.3.1 Ross St Ebbw Vale

Ross St Ebbw Vale is typical of the majority of lean mix widenings undertaken by Council. Ross Street, constructed in late 2004, was a 4m wide local street consisting of 200mm gravel and a bitumen seal. The procedure followed was to widen 1.5m on either side of the existing road by excavation to the blacksoil subgrade, a 200mm layer of lean mix, construction of the kerb and channel, placement of 150mm of lean mix in front of the kerb, and lastly placement of a 25mm asphalt surface. The result, 5 years later is obvious.

Figure 4.11: Rutting of lean mix pavement in Ross St Ebbw Vale

Figure 4.12: Rutting and cracking of lean mix pavement in Ross St Ebbw Vale

Multiple problems have been identified. Severe rutting is occurring in the lean mix areas due to insufficient strength in the lean mix layers. As can be seen there are multiple failure repairs in this area. The second and biggest problem, occurring right across the city, is the interface between the lean mix layer and the existing gravel layer. This vertical join can crack, allowing moisture into the gravel and subgrade which leads to further rutting.

In recent years Council have tried to alleviate this by stepping the second layer of lean mix further into the existing pavement to offset the vertical join however separation is still occurring between the bound and unbound layers.

4.3.2 Boscawan Crescent Bellbird Park

Previously visited in the lime stabilisation analysis, it was noted that there an exception to lime stabilisation works investigated. This section was a full depth lean mix pavement, 10 meters either side of a high pressure gas main, as the 40 tonne lime stabiliser machine was prohibited on top of the gas main by the gas company. The result, given that the rest of the 3.5 year old road is in perfect condition, is disappointing.

Figure 4.13: distant view of Boscawan Cres showing crack over gas main

Figure 4.14: Close up view of Boscawan Cres showing crack over gas main

This section has provided a good comparison between the lime works and the lean mix works, as both pavement types experience the same traffic volumes and have the same asphalt surfacing. Research for this paper suggests that the rounded aggregate particles used in lean mix do not have the particle interlock of gravel pavements and the low ratio of cement does not allow it to act as a cemented layer.

4.3.3 Margret Street Silkstone

The third type of lean mix pavement analysed was located in Margret Street Silkstone. This area of the city contains possibly the worst blacksoil with CBR values typically under 1. The pavement design stipulated 700mm of gravel placed in a boxed excavation, with lime stabilisation of the subgrade, however, given the impending wet season and lack of adequate drainage in the area an alternate was proposed of 350mm deep lean mix pavement, roller compacted over a layer of geofabric with a 25mm asphalt surfacing.

Constructed in late 2005, the pavement is now shows extensive signs failure through block cracking. Although, not clear in the figures below, a wider view of the street shows patterns in the cracking, believed to be where one load from the concrete truck finished and a second load, possibly with a different combination of aggregate, moisture and cement content, started. The possible delay between subsequent loads could indicate that the lean mix did not bind to its neighbour leaving large blocks of base material to move independently.

Figure 4.15: Cracking in Margret Street large enough to fit a key down.

Figure 4.16: Close up view of block cracking in Margret Street

To date there are no signs of movement or rutting of the pavement, possibly due to some of the cracks receiving crack treatment as soon as noticed, however the ones noted during this analysis needed similar treatment before moisture reaches the blacksoil subgrade.

Figure 4.17: Margret Street crack sealing

4.4 Cement and Lime stabilisation

The only project in living memory that has had both cement and lime stabilisation is Suffield Drive, Yamanto, and is a tale of two halves. The initial 600m project was planned for 750mm full depth gravel construction and bitumen seal, however, at the prestart meeting the pavement was changed to lime and cement stabilisation and bitumen seal. The idea had come from a fact finding mission in Melbourne where they were successfully using the same technique. Due to the time saved from using the alternate method, significant funds were saved and the first section was further changed from a two coat bitumen seal to 25mm asphalt wearing course and a second, entirely new, section of 400m long by 6m wide was lime stabilised and bitumen sealed. The result of the multiple design changes was the first section with massive longitudinal cracks and the second in perfect condition.

4.4.1 Suffield Drive first section

Constructed in mid 2006, pavement design for this section of Suffield drive consisted of the following construction process:

- The top 150mm of gravel removed and used for a sidetrack around the construction area.
- The next 200mm layer of sub base was profiled and cast to the right hand side of the road.
- The exposed subgrade was then lime stabilised with 6% quicklime in 2 passes
- The previously cast aside material was then replaced on the left hand side.
- The right hand side layer of sub base was then profiled and cast to the left
- The right hand subgrade was then stabilised as before and cover replaced.
- The sub base material on the entire road was then cement stabilised with 4% GB cement the full 11 meters width in one day.
- A 150mm layer of type 2.1 gravel was then placed on the cement stabilisation before primerseal and 25mm asphalt wearing course.

No significant deformation is occurring in either the pavement or the kerb and channel, so the conclusion can be drawn that the subgrade treatment is working, however the major problem in the street is the massive longitudinal crack in the very centre of the pavement, in some places, big enough to put a cup down, refer to figures 4.18 and 4.19

Figure 4.18: Suffield Drive section 1 longitudinal cracking

Figure 4.19: Suffield Drive section 1, cracking large enough for a coke cup

This very large failure in the pavement can be attributed to 2 factors both noted by Austroads (2003) best practice guide. Firstly, compaction of the lime stabilised subgrade was not correct with no overlap of the second half of the road due to the construction method used. This allows for a "cold" join to develop in the subgrade which has opened up with subgrade movement. This problem is then compounded by the four adjacent run of cement stabilisation on top which according to Austroads (2003)

> *"where the width of compaction for several adjacent runs exceed 6m, consideration should be given to the construction of a planned longitudinal joint to avoid the possibility of the formation of an unplanned longitudinal crack."*

In this case the shrinkage of the cemented layer has compounded the crack occurring in the subgrade. Stabilisation works in this section were performed by a 40 tonne incorporated stabiliser pushing a semi-trailer carrying the binder. The work was delayed several times as the semi-trailer experienced difficulties in the soft subgrade during the stabilisation process and lime had to be spread over the subgrade to dry it out enough to carry the weight of the machinery.

4.4.2 Suffield Drive second section

In direct contrast to the first section, due to the reduced costs of the alternate methods used in the first section, a second section of the road was lime stabilised using a box spreader. The construction method consisted of:

- Pulverising existing pavement with a pass of the rotivator
- 5% lime placed by box spreader, i.e. spread evenly over the open ground
- Further rotivation to mix in the lime
- Application of a 2 coat bitumen seal.

As seen in figures 4.20 and 4.21, the second section of road, built directly after the first section is in perfect condition despite being the same age and same subgrade conditions.

Figure 4.20: Suffield Drive section 2 perfect condition

Figure 4.21: Suffield Drive section 2, good condition even on bends

While the incorporate stabiliser is the favoured machine in most situations, several advantages were observed using the box spreader on section two:

- The weight placed on the open road was equivalent to that of a garbage truck, so did not have the difficulties experienced in the first section
- The project manager visually verified an even spread of lime over the pavement before it was mixed in and slaked. With the incorporated stabiliser, there is some uncertainty that the additive is being spread evenly across the road or at the start and finish of runs.
- Despite the incorporated stabiliser being touted as the most dust efficient way of stabilising, visual observations during both jobs confirmed that the box spread was on par, if not better than the incorporated stabiliser when comparing the dust problem.

As both sections of the pavements are relatively new, close inspection should be undertake to ascertain if any movement of the subgrade has occurred especially due to water ingress in the large cracks that have formed.

Chapter 5 - Pavement Designs

Council has a variety of standards and choices to make in designing pavement layers. The general process that is followed when a new pavement or rehabilitation is required, is a request to Councils in-house NATA approved laboratory to undertake a geotechnical investigation and recommend pavement options. Once the completed report has been delivered to the pavement manager, an option is selected and the design staff are told to design the project around the chosen option. In general, pavement recommendations come from the following sources:

- Department of Main Roads Queensland standards
- Austroads standards
- Former “ICC” design curves
- ICC planning and development standards
- Best fit for budget / constructability / experience.

5.1 Main Roads standards

Issued by Queensland Transport, the Pavement Design Manual is a quality controlled document which provides procedures for the design of pavements for the Queensland Department of Transport. Ipswich City Council is the holder of multiple copies of this document, with the particular one viewed being copy number 432. The registration card nominating the holders name and address was still inside the manual and not returned to Queensland Transport, so this copy would be an uncontrolled copy with no amendments and updates, so could be considered out of date. (Director of Transport Technology 1990)

Major sections and headings in the manual include:

- Introduction

- Pavement design

- Design period
- Design traffic
- Subgrade properties and strength

- Pavement material properties
- Alternate designs
- Optimal solution

- Construction and Maintenance considerations

- Pavement and subgrade drainage
- Permeable pavements on moisture sensitive subgrades
- Full depth asphalt on water sensitive pavements
- Staged construction
- Stabilisation

- Environmental Influences
- Subgrade Evaluation

- Determination of CBR

- Properties of Pavement Materials

- Unbound granular materials
- Cemented materials
- Bituminous materials

- Design Traffic

- Load equivalence
- Design traffic
- Design period
- Traffic Growth

- Design Procedures

- Design charts
- Performance warnings for cemented materials
- Specific design features

- Comparison of designs and implementation

An area of particular interest to pavement designers at ICC and applicable to this dissertation is section 3.12.1 Soft Subgrades.

> *"Subgrades with a CBR below 3 at construction will usually require some form of treatment or working platform to enable construction to proceed.*

Measures which may be employed to facilitate construction include the following:

- *Draining and drying the subgrade*
- *Excavation and replacement of soft material with rock fill or other backfill which has adequate strength when saturated*
- *Provision of a gravel or rock fill working platform*
- *Stabilisation of the top layer of the subgrade*
- *Provision of a working platform of cement treated material*
- *Provision of a lean concrete working platform"*

(Director of Transport Technology 1990)

From the above list, ICC has used most of the methods to strengthen the reactive subgrades usually encountered in the area.

Another section of particular interest to ICC pavement designers is calculation of design traffic. This section sets out the determination of ESA's from present traffic and factored by traffic growth. This section is critical to the success of pavement design as prediction of the pavement deterioration provides the basis for selection of pavement thickness and eventual end of life.

Once the information is gathered the design charts are supplied for varying materials or combinations of materials. Chart types include:

- Full depth granular and bitumen seal
- Granular with an asphalt wearing course
- Full depth asphalt and bitumen seal
- Cemented material with asphalt wearing course
- Full depth cemented material and bitumen seal
- Cemented material, gravel and asphalt wearing course
- Cemented material, gravel and bitumen seal

The charts are generally usable directly in a format for ICC requirements with the lower limits on the charts being CBR3 and $1 * 10^5$ ESA's. While these limits might not be low enough for some of the situations encountered at ICC, meeting the minimum specification given on the charts will ensure the pavement design exceeds the requirements of the situation.

A worked example of Main Roads specification design chart is included here for reference.

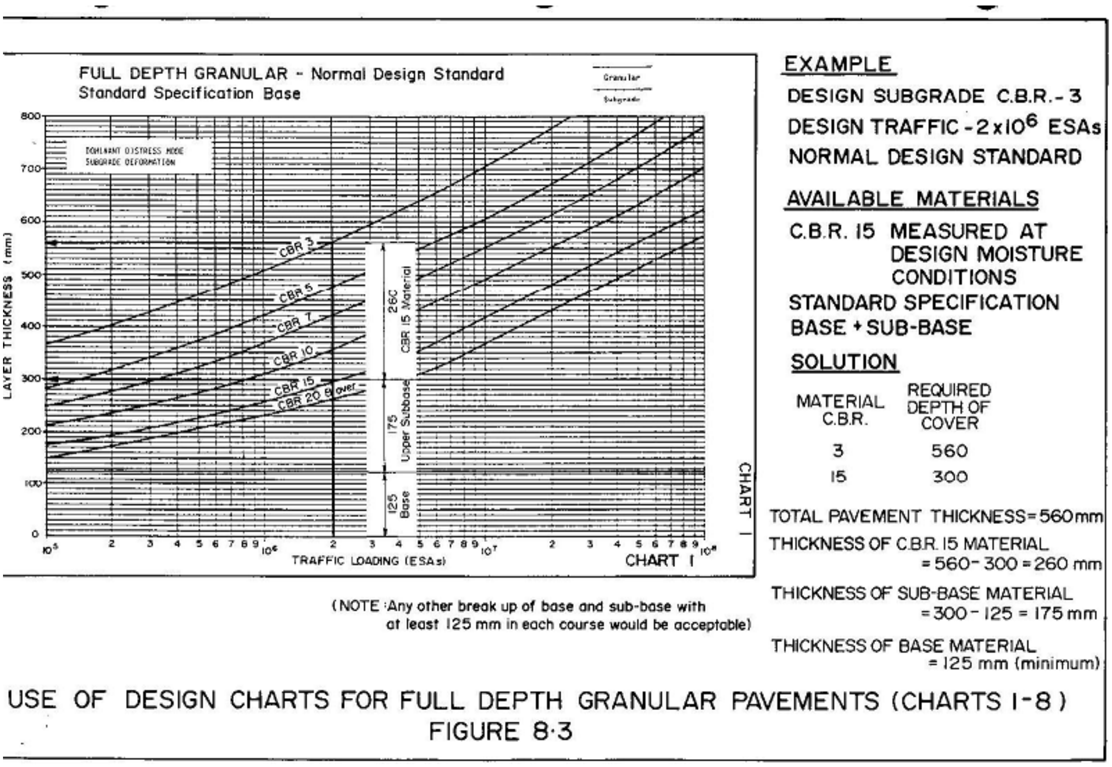

Figure 5.1: Example use of Main Roads design charts (Director of Transport Technology 1990)

Overall the manual is very thorough and should be required reading for any students of pavement design and all project managers in Council. It provides a justifiable design for pavement given the design traffic and subgrade conditions, however the use of the manual is tempered by the fact that it is not a controlled copy and there may be significant errors and omissions by it being out of date.

5.2 Austroads standards

Another source of pavement design guidance in Australia is "Pavement Design – A guide to the Structural Design of Road Pavements", a manual produced by Austroads (2004) which is a part of Standards Australia. The information contained within is very similar to the information contained in the Main Roads design manual, and it is noted that Department of Main Roads Queensland is an Austroads member.

Chapter headings are very similar to the Main Roads manual, with design of rigid pavements getting its own chapter. Once again design charts are included and are quite simple to use. Once the CBR of the subgrade is known and a determination of the design traffic (ESA) is made, one can simply read off the thickness of granular material required to support this amount of traffic. The guide contains various example design charts for most combinations of pavement types including:

- Asphalt and granular over subgrade
- Asphalt over subgrade
- Asphalt and cemented material over subgrade
- Asphalt, granular and cemented material over subgrade.

Being an Australia wide publication and not just for high traffic main roads, the charts allow for a CBR of 2.0 which is more applicable to the reactive subgrades found in the Ipswich area. The charts also include an empirical formula which allows the user to calculate their own thickness of gravel for CBRs not given.

Again, this document does not appear to be controlled as there are no obvious signs of a controlled document number, however errata sheet AP-G17/04 is filed loosely inside the front cover.

Examples of the design charts are shown in figures 5.2 and 5.3

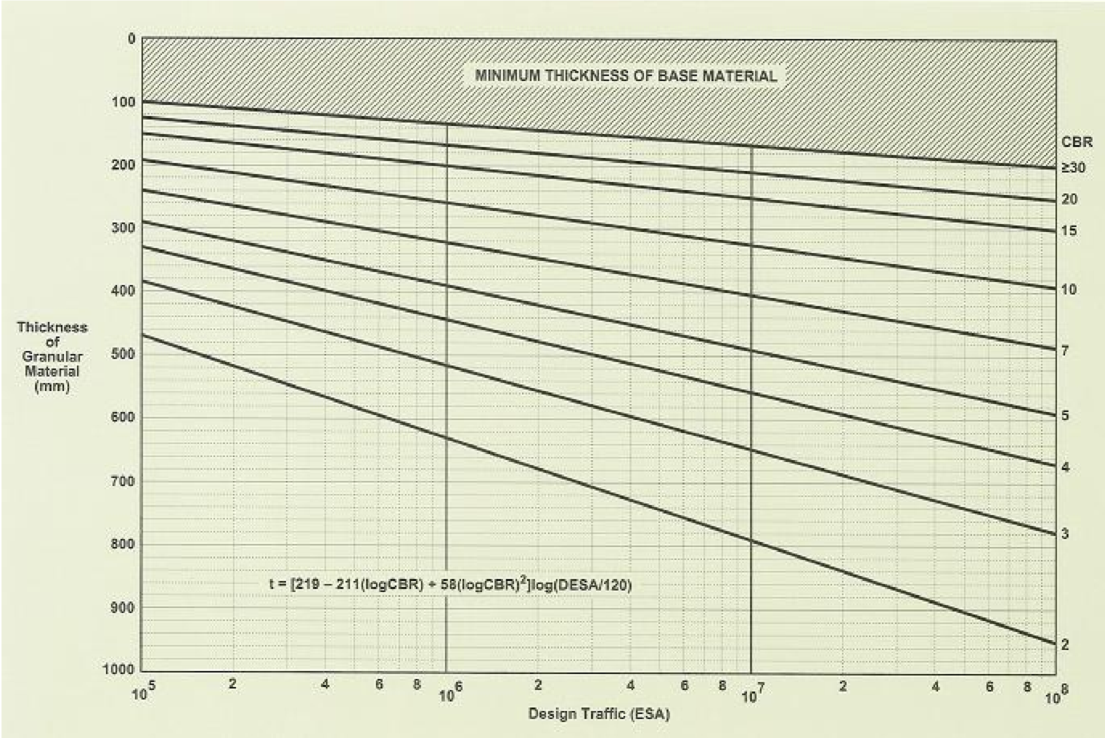

Figure 5.2: Austroads granular design chart (Austroads 2004)

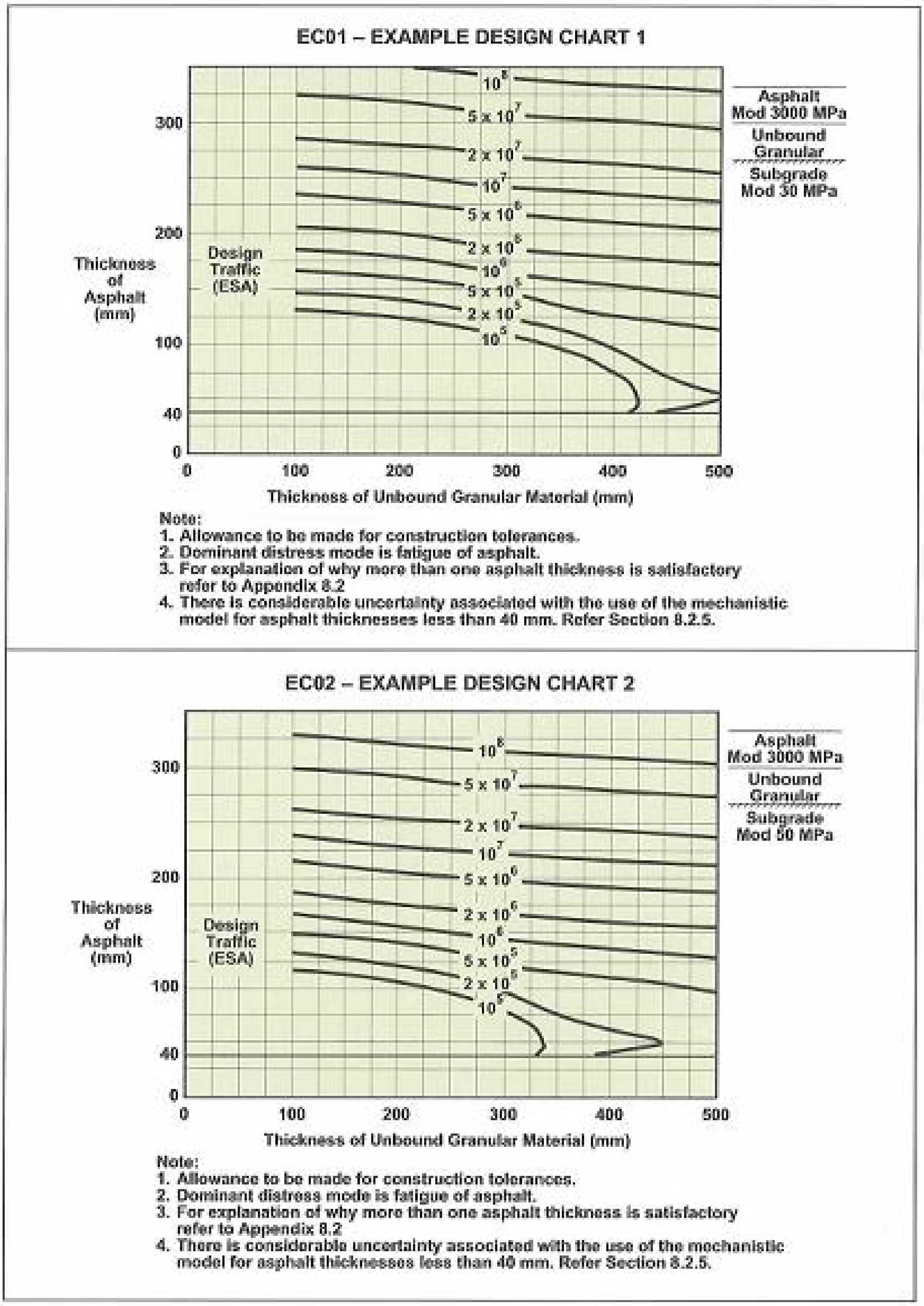

Figure 5.3: Austroads example design charts (Austroads 2004)

One major difference between the two documents is their currency, with the Austroads manual being published in 2004, compared to the Main Roads manual, 1990. As a recommendation out of this dissertation, Ipswich City Council should check both documents for latest additions and erratum and ensure that controlled copies are updated whenever changes are made.

5.3 Former "ICC" design charts

The primary source of pavement design information specific to the Ipswich conditions is the former "ICC" design charts. The correct name for the document is "Ipswich City Council, Department of works, Design manual No. 2, -/9/82" (Ipswich City Council 1982). It is called the former "ICC" design charts, not because it is not used anymore, but because the document belonged to Ipswich City Council before the merger with Moreton Shire Council in 1995 to become the even larger Council of the City of Ipswich. The document was prepared by the design office with plans numbered 19505, 19506 and 19507 approved for use by the City Engineer on 27/6/79 (name not distinguishable). The plans state they are a compilation of information from Queensland Main Roads Department Material's Manual and the Country Roads Board Technical Bulletin No. 26 Part B. Plans are attached in appendix D.

There are two known copies of the document in existence, one with the Rehabilitation Manager and one with Council's soil laboratory. By current document control standards, it is very poor, with no contents page, no recent revisions being undertaken (document No. 2 suggests second revision in 1982), no document control system, no indication of ownership and outdated information, however, as a basis in design it is an invaluable source of information and outdates many other the Austroads and Main Roads standards. The documents themselves are tattered and torn and being a thin 10 page A4 document could easily be lost forever, and a recommendation to come from this dissertation would be for the document to be electronically captured, either re-typed or scanned for permanent electronic storage.

Stepping through the document itself, it starts with an in depth design basis explaining CBR, traffic volumes and the equivalence of commercial vehicles. From this information the user then selects a design curve letter from a table, based on the traffic volume, with A being 0 to 15 commercial vehicles in both direction to G which is over 4500 vehicles. The initial traffic volume is multiplied by a growth factor depending on required design life and a constant annual growth percent and then the initial table checked to see if the chosen curve is still applicable. Once this information is finalised, plan 19505 allows the user to read off the required depth of gravel by extrapolating off the chosen curve from the CBR value of the gravel.

Part B of the document makes recommendations for AC wearing courses and full depth asphalt pavements by reading similar information off plan 19506. The final section of the document looks at AC overlays to reduce pavement deflection below an allowable limit for a particular street type.

Overall the document contains some basic and valuable information for the junior engineer or pavement designer and returns results similar to the Austroads or Main Roads standards, however it has some limitations that need to be realised.

- Lack of document control does not assure the user has the current information required.
- Adequate training and instruction needs to be given before blindly following the document.
- The traffic classification and description of roads no longer align with current definitions of use.
- The growth factors allowed for in the document may no longer be valid, with Ipswich experiencing unprecedented growth, the largest factor of 6% is out of date
- No indication is given of what the makeup the gravel pavement should be, i.e. layer height and types
- No indication of pavement drainage requirements and protection from the underlying subgrade

Despite these short comings, the document has proven a very useful tool in the past, however may not stand up to legal scrutiny should a problem occur due a pavement failure based on the recommendation contained therein.

5.4 ICC Planning and Development standards

A standard applied by another department of Council, Planning and Development, comes from the Ipswich Planning Scheme. With the unprecedented growth occurring in the Ipswich area, a set of guidelines were created to assist the developers in knowing the acceptable pavement depths while creating subdivisons in Ipswich. A section of particular interest to this research is "Division 2 – Flexible Pavement Design". The scheme starts with two very important notes:

> *"Note 1.2A*
>
> *(1) This section is intended to facilitate the checking and approval of proposed pavement designs for roadworks associated with reconfigurations and building development works.*
>
> *(2) This section is not intended to be used in lieu of design manuals"*
>
> (Ipswich Planning Scheme 2006)

The document outlines testing frequencies, specifications for pavement materials (refers to Queensland Transport specifications) and indicates the design ESA's based on the road classifications: access place, access street, collector, trunk collector, sub arterial, industrial and arterial (figure 5.4). As this scheme is mainly targeted at new subdivisions and new works, it could be assumed that it is not possible to do traffic counts to calculate the design ESAs.

Table 1.2.2: Design ESA's by Road Class

Description	Road Class	ESA's
Access Place	A (30 Lots Max.)	5×10^4
Access Street	A1(75 Lots Max.)	1.0×10^5
Collector	B (300 Lots Max.)	2.0×10^5
Trunk Collector	C (1000 lots Max.)	1.0×10^6
Sub-Arterial	D	2.0×10^6
Industrial	E	7.0×10^6
Arterial	F	DMR Design Standards

Figure 5.4: Design ESA's by Road Class (Ipswich Planning Scheme 2006)

Similar to the Main Roads and Austroads charts, once the CBR of the subgrade and road class is known it is a simple matter of reading off the required minimum pavement thickness excluding asphalt surfacing. Table 1.2.3 has been reproduced here for reference

Table 1.2.3: Minimum Pavement Thickness

Minimum Total Pavement Thickness (mm) (excluding AC Surfacing)							
CBR of Subgrade	**A**	**A1**	**B**	**C**	**D**	**E**	**F-Refer all Type F Roads to DMR**
1 and 2	Refer to section 1.2.4(1)(b)						
3	450	470	495	550	560	670	
4	375	395	420	465	520	620	
5	325	340	360	390	480	580	
6	290	310	325	350	450	550	
7	265	280	295	320	425	520	
8	240	255	265	295	400	500	
9	225	230	245	275	380	480	
10	225	225	225	255	365	465	
12	225	225	225	225	325	430	
14	225	225	225	225	305	400	
16	225	225	225	225	290	375	
18	225	225	225	225	275	355	
20	225	225	225	225	275	335	
Minimum Course Thickness							
Asphalt	25	25	25	50	50	50	
Base Course Type 2.1 (Min CBR80)	125	125	125	125	125	125	
Upper Sub Base Type 2.3 (Min CBR45)	100	100	100	100	150	150	
Lower Sub Base Type 2.5 (Min CBR15))	As required to obtain minimum thickness (100mm minimum layer thickness)						

Source: A, A1, B, C type ARRB Special Report No. 41 - Figure 7 / D, E, F type Queensland Department of Main Roads Pavement Design Chart 1.

Figure 5.5: Pavement thickness for Road Class (Ipswich Planning Scheme 2006)

Special mention is made when the CBR of the subgrade is 1 or 2. A blanket rule is applied for CBR 2, 100mm of gravel added to the CBR 3 design and for CBR 1, 200mm of gravel is added to the CBR 3 design. The use of this chart is simpler than the design chart seen previously and also spells out exactly the layer thickness and gravel type to be constructed. The planning scheme also gives some worked examples to guide the user in the correct application of the tables. To date, use of the design chart is very limited in the Engineering Services department.

5.5 Best fit for budget / constructability / experience

While the former methods mentioned above have been demonstrated and proven through field experience and come from reliable sources, as Ipswich City Council is a Local Government entity, some of the decisions around pavement choices are politically driven. In order to stretch the Council budgetary funds as far as possible, sometimes minimum treatments are undertaken to relieve the immediate problem at the possible sacrifice of full 20 year pavement life. Sometimes these minimal treatments can get unexpected good results and thus Council gets extremely good value for money, however as seen in Chapter 4, some pavements are failing within only a few years.

5.5.1 Minimum seals

An example of Council's innovative and thrifty policy is the minimal dust seal trials that Council has performed in the past 15 years. As an alternate to full pavement design, Council has undertaken to seal a small proportion of their gravel road network each year with a bitumen seal after a gravel maintenance pass. The roads are signed as sealing trials, and if the roads fail Council has the option to revert back to the unsealed pavement state. To date these roads have performed extremely well with no roads being reverted to gravel only. The only problem encountered has been minor edge breaks due to the seals generally being only 4m wide and for vehicles to pass, requires one or both to drive off the edge of seal. These minimum seal type roads are in the rural, hilly areas of the city, and thus the subgrades are generally ridge / rocky material with many years of maintenance gravel being placed on it. As this does not fall into the main theme of this dissertation of pavements on reactive subgrades, further analysis of minimum seals can be left for research in the future.

5.5.2 Case Study – Pine Street Flinders View

Another example of minimal pavement treatment being the best fit for budget is Pine St Flinders View. Pine Street is a local collector road with a traffic volume of $2 * 10^5$ ESA's per year. The project involved rehabilitation of the road pavement and replacement of the kerb and channel from Kurrajong St to Hibiscus St. A full geotechnical report was undertaken by Council's soil laboratory and the investigation report is shown in appendix E.

The investigation reported that the road, constructed in the 1980s, was exhibiting all the typical signs of distress, with cracking, rutting, deformation, potholing, subsidence and major failure repairs. The subgrade was broken into 2 sections, chainage 0 to 220 having CBR 2 and chainage 220 to 395 having CBR 10. The increase in CBR at the southern end could be attributed to the increase in elevation at this end of the street coming into a seam of ridge gravel. Importantly the existing pavement was about 330mm thick and met a type 2.4 specification.

The investigation report returned the following options to reinstate the road to a serviceable level. Note: concentration is on section 1 only as this is the reactive subgrade section.

- Full gravel pavement 545mm and bitumen seal. (Former ICC design curves)
- Full gravel pavement 550mm and bitumen seal. (MRD design manual)
- CTB gravel 335mm with 40mm AC (MRD design manual)
- Gravel 425mm and 40mm AC
- CTB gravel 165mm, 125mm gravel and 40mm AC

Other options considered were:

- Stabilisation with 3.0% Fly Ash Blended cement for 200mm and bitumen seal
- Foam bitumen stabilisation 200mm deep

Given the success of the trials of foam bitumen stabilisation and the minimum impact on the local residents, the project manager proceeded to gather estimates and quotes from suppliers for foam bitumen stabilisation. The costs and benefits for foam bitumen stabilisation on Pine Street is continued in chapter 7.

The option chosen was insitu stabilisation with 3% Fly Ash Blended cement 150mm deep and 30mm AC. The estimated cost was approximately $50,000 cheaper than foam bitumen stabilisation. Whilst this option is not the full depth specified by the MRD manual, with the pavement being an average of 330mm deep, the rehabilitation manager gambled on the fact that greater than 150mm of gravel exists in the pavement and when combined with the asphalt layer, will help take some of the traffic load. Given the financial restriction placed on the job, the insitu cement stabilisation appeared to be a reasonable option, however, the research from this paper poses some questions that should be asked:

- Were the implications of dust on the health of the residents considered for cement stabilised works? Were the subsequent clean up and complaint costs considered in the estimate?
- Did the project manager consider that the in-situ option does not allow for the underlying layers to be investigated for significant failures that were missed by the random sampling of pavement investigation, which could lead to new failures in the completed pavement?
- Will the cement stabilised layer and asphalt wearing surface combination lead to premature failures in the future as seen in the case studies in chapter 4?
- Were ICC managers and councillors made aware of the impact the minimal treatment will have to the design life of this pavement?

Given the current economic climate and associated tight budgets, performing a minimal treatment, such as the dust seals, is a good option to reinstate the road to a serviceable level, as long as all involved are aware of the risk of premature failures and the associated embarrassment that may occur to Council. The stabilisation works proceeded in late September 2009, and the pavement is expected to be monitored for performance.

Other factors which weigh heavily on the choice of pavement to be built is the constructability. As seen in chapter 4, the use of lean mix pavements, especially in small widening situations, can produce significant savings in time, which means that its use is widespread despite the inherent problems that occur. An important factor in the decision regarding what pavement design will work in a given situation is the experience of the designer. Between the Laboratory Manager and Rehabilitation Manager there is over 60 years experience in pavement design, mostly with ICC, so their ability to predict a minimal treatment that will work in a given situation should not be overlooked.

Chapter 6 - Improvements to existing methods

6.1 Cement stabilisation

Significant cement stabilisation works have been going on in Ipswich for about 40 years. The research for this paper involved access to projects over the last 10 to 12 years, so any failures that were observed could be considered premature, as the expectation is the a pavement should last 20 years.

Research into the standards currently used by the Main Roads department and other Councils and the recommended quantities by Council's own stabilisation contractor, Stabilised Pavements Australia (SPA), indicate that 3% GB cement is the norm. This allows a minor amount of movement in the pavement and minimise block cracking reflecting up to the sealed surface. Once cracking sets in, water can ingress into the pavement gravel and failures occur. This was seen in the individual case studies presented.

The analysis of the cement stabilised works also revealed that roads sealed with a 2 coat bitumen seal outperformed the asphalt seals every time. Research indicates that this success is due to increased ability of bitumen seals to flex with the pavements over the cracks, so a conclusion can be drawn that a rubber or polymer bitumen seal over cement treated stabilisation work would protect the pavement greater than the standard bitumen seal or asphalt.

An alternate way of preventing the cracking seen so frequently with cement stabilised works is to place a layer of geofabric / geotextile over the stabilised layer before subsequent layers of gravel or the final seal. This method is commonly used in Europe, the USA and the Northern Territory with great success. According to Rassmussen and Garber (2009), there are 3 functions behind the use of nonwoven geotextile material as an interlayer for cement stabilised pavements;

- Separation: to stop crack and joints from reflecting to the surface layer. With the absence of cracking appearing in the finished AC surfaces, there is a lower chance of water infiltrating into the pavement causing the multitude of failures that we are seeing occurring in the Ipswich area.

- Drainage: should water infiltrate through the seal layers, the water should drain into the interlayer and then along the crossfall to the pavement edge.
- Bedding: the interlayer can reduce the bearing stresses from the traffic loads.

Rassmussen and Garber (2009) back up their theory with a case study of a highway project in Missouri, south of Kansas City, where two nonwoven geotextiles, a Geotex 1201 and a Geotex 1601, manufactured by Propex, were used over an existing concrete pavement which showed considerable distress and reflection cracking. The interlayer was followed with a 25mm surfacing layer and to date appears to be a success, however, long term performance of the section will have to be monitored.

Here in Australia, proprietary products are also available that also perform a similar job to the Geotex 1601 indicated above. Multiple councils, Queensland Transport and the Roads and Traffic Authority NSW have been laying Fibredec fibreglass reinforced seals as a strain-alleviating membrane to control reflective cracking (Roads Feb-Mar 08)

Figure 6.1: Fibredec fibreglass reinforced seals (Roads Feb-Mar 08)

Other improvements with cement stabilisation are involved with the actual mechanical process of stabilisation, however this will be investigated in the following sub section.

6.2 Lime Stabilisation

Like cement stabilisation, lime stabilisation has been going on in Ipswich for over 40 years. The work of Bob Gamble in 1968 documented the optimal lime content for the blacksoil conditions found in Ipswich. It is unfortunate that this information has to be found during research for a paper such as this. It is suggested that project managers in charge of lime and cement stabilisation should read this document when planning stabilisation works.

The research of this paper revealed the deficiency of knowledge surrounding the processes involved in lime stabilisation. According to Austroads (2003), some of the critical parts of the stabilisation process not understood by project staff at Ipswich include:

- Two pass mixing. The majority of projects undertaken at Ipswich are 5 to 6% quicklime mixed into the pavement with an incorporated stabiliser. This will require 2 passes. To overcome a potential problem with mixing to full depth, the first pass should be mixed to only 70 to 90% of the final depth. When the pavement bulks due to this first pass, the second pass at full depth ensures that a lens of only partially stabilised material is not left at the bottom. To date, this requirement has never been specified to the contractor, nor checked and understood by the project manager.

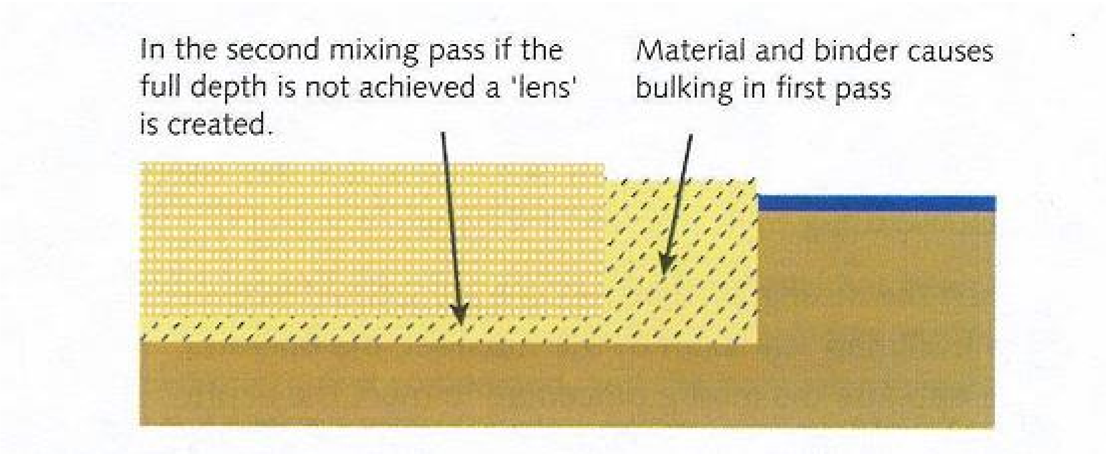

Figure 6.2: bulking problem with 2 pass mixing, Austroads (2003)

- Compaction and mixing patterns. To avoid cold joins between horizontal passes, it is important that compaction of the stabilised layer does not occur within 300mm of the edge of the run. When the second pass begins it should then overlap the previous pass to prevent the cold join. Some of the current practices at ICC involve exposing only one side of the subgrade at a time to allow the street to remain open to traffic, however unless at least 300mm of the first side is exposed then this cold join can develop.

- Number of passes in a single day. According to the guide to best practice for the construction of stabilised pavements, Austroads (2003), any more than 3 passes side by side in a single day will lead to significant shrinkage which may separate the pavement in the middle of the road. As previously seen, the combination of a cold join in the subgrade and 4 side by side passes on Suffield Drive Yamanto has lead to severe shrinkage in the middle of the road.

Figure 6.3: Severe pavement separation on Suffield Drive Yamanto

- Curing: light and frequent sprayed water is required until sealing occurs or the next layer placed, otherwise surface cracks and ravelling occur under traffic.

6.3 Lean mix pavements

Given the severity of the failures that have occurred on lean mix widenings, the best recommendation / improvement is to discontinue the use of lean mix, however, the simplicity of placing the material, ease of compaction and ability to get into tight corners means that the use of lean mix will continue.

The project managers are aware of the problems of the bound and unbound layer separation, so the question must be asked – why does Council continue to use it? Ipswich, being a very old city has a great number of streets without kerb and channel, and while the pavement in the middle may be serviceable, the residents often request kerb so they can be equivalent to the new developments and to prevent minor stormwater runoff problems. As the centre of the road does not require work, often the design solution is to excavate 1.5m each side of the road and install kerb. Whilst excavation to that width is simple, placing, mixing and trimming gravel in that width is not possible due to Council only owning larger 3m graders. Council did own a smaller grader that could do this work, however it was sold off as it was not being used due to work crews using lean mix.

Council has trialled several methods to place gravel in these confined spaces such as a bobcat loader using a loam spreader, however this machine did not have the ability to mix the gravel to achieve the optimum moisture and hence the correct compaction. Another machine on the market is a bobcat based grader attachment, and a recommendation from this dissertation would be to trial one of these machines for workability it tight confines.

As indicated in Chapter 4, Council has been searching for methods for stopping this interface crack, for even if gravel were used, a cold join would exist and the possibility of cracking increases. One such method is shown in the hand drawn figure 6.4.

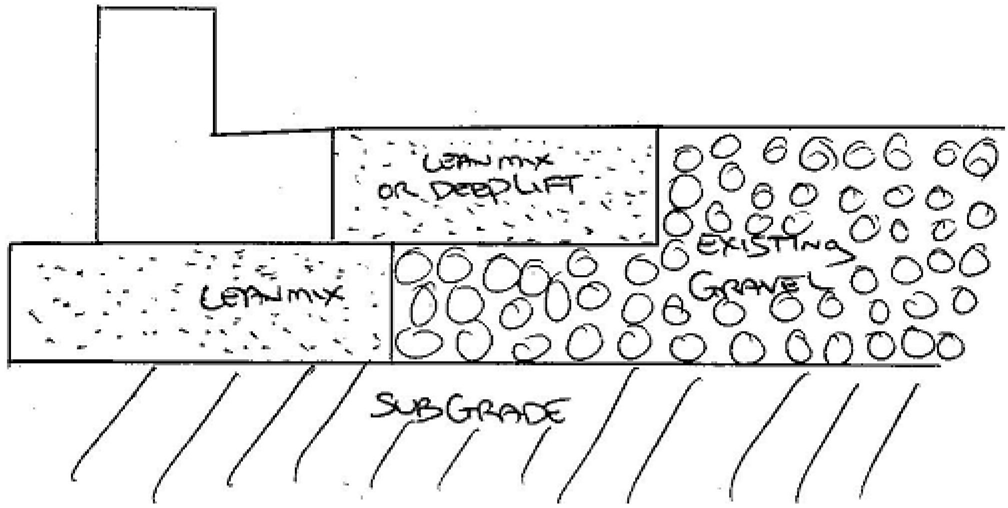

Figure 6.4: Stepped lean mix construct, hand drawn by author

This method of stepping the construction joins in the layers appears to be having some success, however it is proving uneconomical. Two problems occur if the stepped section is excavated at the same time as excavating for the kerb and channel.

1) Often the streets are relatively narrow (under 6m) and excavating the pavement on both sides of the road at once will leave only a 3 to 4 meter trafficable lane, making it impossible for two way traffic and insufficient width to turn out of driveways due to the excavation barriers. Whilst it is possible to do one side of the street at a time, saving will be lost due to two visits from kerb crews, surfacing crews etc.

2) The concrete for the kerb and channel is delivered by concrete agitator truck. Due to the height above the ground of the kerb machine hopper, the truck has to be fairly close, as there is insufficient fall over a great distance. To do this the truck would have to drive with one set of wheels inside the excavation and one set on the normal pavement level. This creates a dangerous situation for the workers on the kerb machine from the possibility of the truck tipping over while delivering concrete. This practice has been prohibited by the ICC Work Place Health and Safety committee.

Thus the only practical method of stepped construction has been for a profiler to make a second visit to the site to over excavate the top layer, before the final layer of lean mix or deep lift asphalt is placed.

The stepped construction has only been a recent introduction and the long term success is yet to be realised. This research suggest that there is still a significant cold join in both layers of pavement and will be the first place to fail when movement of the subgrade occurs. An improvement recommended from this research would be an interlayer of a geosynthetic material between the lean mix and kerb and then placed under the base layer of lean mix out into the pavement. This would effectively bridge the join above the subgrade, with the disadvantage of requiring the full excavation to be done at once or the geosynthetic being laid in two pieces and tied together with a 100mm overlap once the stepped box is excavated.

The join in the base layer presents more of a problem. As the existing road is usually serviceable, generally only the widened section is surfaced. This creates a cold join at the interface of the old and new seals. A suggestion to improve this would be to use a bobcat profiler to take an extra 100mm in width off the existing seal and step the surfacing over onto the old road. With all this stepping further onto the old pavement, the width frequently means that there is not much of the old seal left, and if a full width asphalt overlay is to be performed, then a product such as the previously mention Fibredec could be used as an interlayer to prevent the reflective crack from occurring. Failure to take any of the options to reduce cracking will only lead to more “Ross Streets” with rehabilitation required after only 5 years.

Chapter 7 – Alternate Technologies

The main thrust of this research is in finding alternatives to the usual cement and lime stabilisation whilst trying to make a saving over full depth gravel pavements.

Several options exist which have not been employed by the work crews at ICC. The options investigated here are:

- Foam bitumen stabilisation
- Geosynthetics
- Mass foam blocks
- Full depth asphalt pavements
- Other innovative Australian pavements

Some of these technologies have been experienced by some project managers at ICC. Foam bitumen has been performed by contractors on some of the local rehabilitation jobs, however, the day labour team have never used it and have no understanding of the principals of how it works and how to apply it. Geosynthetics have been used in the form of fabric but Geogrids have never been used, despite being demonstrated by the supplier several times. The other easily implemented option is full depth asphalt pavements as seen on many highway construction works around the city. Despite the success of the method, ICC full depth asphalt pavements has been limited to a single base layer of asphalt.

7.1 Foam Bitumen Stabilisation

Mixing bitumen with an existing pavement can add strength and durability while still allowing flexibility, however it is difficult to mix directly into the pavement and can be done either by bitumen emulsion or foamed bitumen.

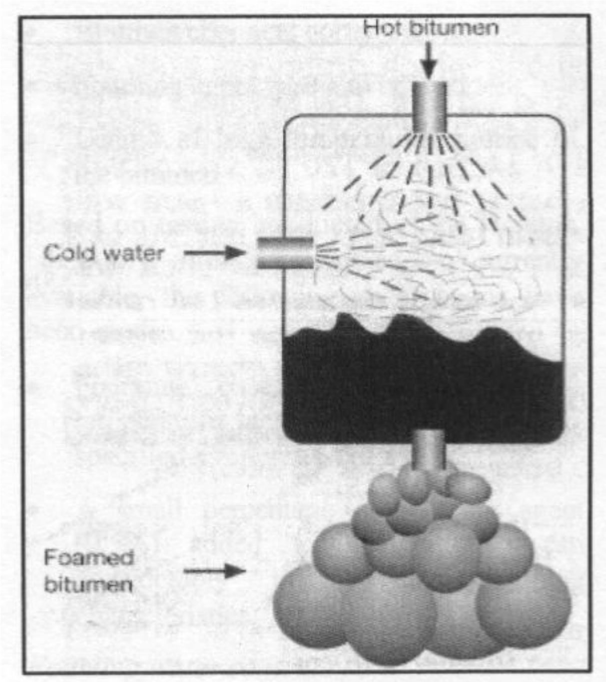

Figure 7.1: Foamed bitumen principal (Jones 2004)

The short term effects of foamed bitumen is that the pavement has a strength of around 1600Mpa but acts similar to a normal granular layer, so enjoys the best of both worlds, strength and flexibility. (Jones 2004). The end product could be considered an asphalt base, and while design charts do not yet exist for foam bitumen bases, direct extrapolation is possible off the design chart for an asphalt pavement of modulus 1600 Mpa, making the process a simple look up answer. Example design chart is attached in appendix F.

Foam bitumen technology is not new in Australia. Queensland Transport Main Roads department have been conducting trials since 1996 with the largest operation undertaken being the New England Highway just outside Warwick, where 17 kilometres were foam stabilised 300mm deep and sealed with a 2 coat bitumen seal. To date only minor cracking can been seen in the pavement. During a briefing session with Main Roads expert, Jothi Ramanujam, many of the secrets of foam bitumen were revealed:

- Foam bitumen is created by injecting water into hot bitumen which cause the bitumen to expand to approximately 15 times its original volume before it starts to collapse back to its original volume in 12 to 15 seconds.
- While the bitumen is expanded it is mixed with the pavement material where it coats the fine particles and if still hot assists with compaction
- Main Roads have found that the ideal quantities of additive are 3.5% class 170 bitumen during stabilisation, with 2% hydrated lime mixed in beforehand which is a must to allow for early trafficking of the road.
- Old stabilised patches of pavement must be replaced with fresh gravel otherwise residual lime in combination with the new stabilisation will make the pavement too strong and rigid leading to cracking.
- It is better to make the pavement deeper (250 to 300mm) rather than trying to make it stronger. Over design will lead to cracking.
- Stabilising only 150mm deep will allow the pavement performance to be subject to subgrade impact and fatigue.
- Use a SAMI seal (strain alleviating membrane interlayer) to prevent shrinkage cracks on the surface.
- Control the amount of additive going in. Beware of start and finish of runs where additive can build up.
- Pavement needs to conform to MRS 11.05 “C” grading to give confidence stabilisation will work.
- Inappropriate applications –
    - ambient temperature under 10^{o}C.
    - unsuitable pavement material grading and plasticity. The insitu material requires 20% of the material to pass the 0.075 sieve, so the treatment is not suitable for all roads, noting that when the profiler picks up the material it may crush further. Too many fines creates a plasticity problem.
    - Roads with 50mm asphalt layers will not pulverise properly due to the size of the machine and may end up as large pieces in the new pavement.
    - Mix design testing indicates the foam bitumen is inappropriate.

- Inappropriate with high organic / sulphate content or ferric materials in pavement. Sample and investigate first and make this a hold point.

- Immediately compact behind the stabiliser or material being placed on the job to aid compaction while the binder is still warm and fluid.
- If material is pugged off site then it should not be laid with a paver as the maximum depth achievable is 200mm which is not ideal and 2 layers it not acceptable.
- In-situ stabilisation: prepulverise to reveal unsuitable or wet areas and replace as necessary. Additive harder to control and safety and environmental concerns. Problems with high or low binder mixes are not apparent until afterwards.
- Ex-situ mixing and replacing: mixing easier to control with load cells adding the correct additive, deficiencies in grading easily corrected with sieving and adding new material if required, visual inspection of subgrade making it possible to replace problem areas, however multiple handling and trucking of material to remote site significantly increases cost.

Figure 7.2: Foamed bitumen ex-situ plant producing mix

The foamed bitumen process comes with many benefits and some disadvantages:

Benefits:

- The process is an easy application, with foamed bitumen sprayed directly into the recycling chamber or pug mill.
- The process minimises disruption to traffic/ business and residents by completing the works in a shorter period. In general, the road can be opened in the morning and have the foam bitumen placed and compacted ready for traffic that afternoon.
- The material can be placed in isolation. Should a short section have to be done, say within school hours only, then the small section of work can be completed to not disrupt the school pickup. Also suitable should inclement weather arrive, the pavement can be closed up minimising the chance of have subgrade open to rain.
- Rapid strength gain due to the additional binder of lime. The road can be trafficked as soon as compaction is complete.
- The equivalent depth of foamed bitumen layer is much less than a full depth gravel pavement, minimising the requirement to relocate services and the chance of hitting unmarked services, gas , water etc.
- The process can be considered a “green” alternative, with over 95% of the existing pavement reused and replaced in the road, alleviating the need for disposal or stockpiling the spoil and saving precious gravel resources for roads where foamed bitumen is not suitable.
- Other indirect savings other than the direct replacement of a gravel layer, e.g. foamed bitumen treatment does not require a primerseal before the asphalt layers, saving approximately $3 per square meter.

Disadvantages: (Jones 2004)

- Special equipment required for the foaming process.
- The cost of bitumen foaming is significantly more than similar stabilisation works such as cement.

- The insitu pavement material has to conform to MRS "C" grading or material added to bring it within range
- Special attention is required during the seal design to ensure stripping does not become a problem.

Queensland Department of Main Roads have performed many trials and have come up with a firm set of recommendations which ICC can transform to their own requirements. A full analysis of the cost benefits of this treatment will be analysed in chapter 8, and given the proven track record, foam bitumen can be easily added to the pavement technologies in ICC.

7.2 Geosynthetics

The idea of Geotextiles is not new. Even in ancient Egypt, they found that mixing fibres and some natural vegetation improved poor soil quality. In the 1920's, areas of the USA used cotton fibres to reinforce subgrades, however it wasn't until recently that modern plastic technology like polypropylenes, polyesters and polyamides have brought Geotextiles, or rather Geosynthetics to the forefront in road construction technology (Geotextiles in road construction 2009).

Geosynthetics covers a whole range of materials that perform a variety of functions. The materials can be identified by function they perform (Bathurst 2009):

- Separation: This is the most common use of a Geotextile at Ipswich Council. Whenever the typical blacksoil is encountered at the bottom of an excavation, a layer of geofabric is laid. The main aim of the geofabric is to stop the fines from the subgrade from migrating into the sub base layers due to the movement and pumping of moisture. Similarly it stops the gravel materials from penetrating the soft subgrade soils. This mixing of the subgrade with the gravel layers leads to the premature failure of the road. While the theory behind its application may not be understood in the field, the application of geofabrics of Ipswich's heavy blacksoil subgrades is a cheap insurance policy for the overlying pavement.

- Filtration: The geofabrics also allow movement of moisture into drainage systems while retaining sand and soil particles on the upstream side. Typical application at Ipswich is subsoil drains laid either side of the new pavement, designed to intercept subsoil water before it gets to the pavement layers and weakening them. The geofabric wrapped slotted plastic drainpipe is laid in a bed of pea gravel (<5mm aggregate size), with the geofabric allowing water into the drainage pipe while retaining the sand particles.
- Drainage: While not often being used at Ipswich, draining of less permeable soils, such as removing pore water pressure behind a retaining wall, is also a function within the capabilities of Geosynthetics.
- Reinforcement: This is the area of particular interest to this research. Geogrids have the ability to work with the particles in the gravel to add tensile strength to the pavement. While this research will concentrate on pavements, the Geogrids also allow embankments to be built at steeper angles and can also bridge voids.
- Fluid / Gas containment: Mainly used in landfill situations where the geosynthetic can act as an impermeable barrier to stop the waste runoff entering nearby water tables
- Erosion Control: A geosynthetic is also useful in prevent rainfall impact and surface water runoff from creating erosion problem before embankments are able to stabilise with vegetation.

The particular application that this report centres on is the reinforcement of pavement layers, especially in poor subgrade conditions. The technology works by increasing the depth of the confined zones and the magnitude of confinement. The aggregate interlocks and is confined within each cell in the grid, which transfers the stresses in tensile forces horizontally in the grid, which is resisted by the strength of the grid itself, typically 40kn/m.

Case studies from local nearby Councils indicate that typical gravel savings of up to 240mm are possible with the inclusion of a layer of geogrid, however these savings are only realised when the CBR rating of the subgrade is 3 or less. Above CBR 3 and the gravel depth savings are less noticeable.

The success of geogrids dates back as far as 1996 in Australia. Geogrid was used successfully in the relocation of the 10 Terminal Regiment base to the banks of the Ross River in Townsville. The 1 kilometre by 11 meters wide access road had to be built across a tidal flood plan of mangrove mud and silty sands with a CBR less than 2. The insitu surface was not even capable of carrying construction traffic. The design used was a layer of geofabric laid directly over the natural ground, 2 layers of geogrid interlocked with a layer of 200mm thick 20mm aggregate and a 100mm layer of 20mm aggregate.

Figure 7.3: Granular platform over Tensar SS30 Geogrid (Schaeffer 2007)

To date, the pavement has been inundated several times by king tides and carries significant loads such as Army trucks and transporters and is generally subject to constant heavy traffic. In March 2007 roughness tests were taken, and other than some minor sections around the bridge abutments, the test faired very well with roughness counts approximating that of new construction works despite being 13 years old.

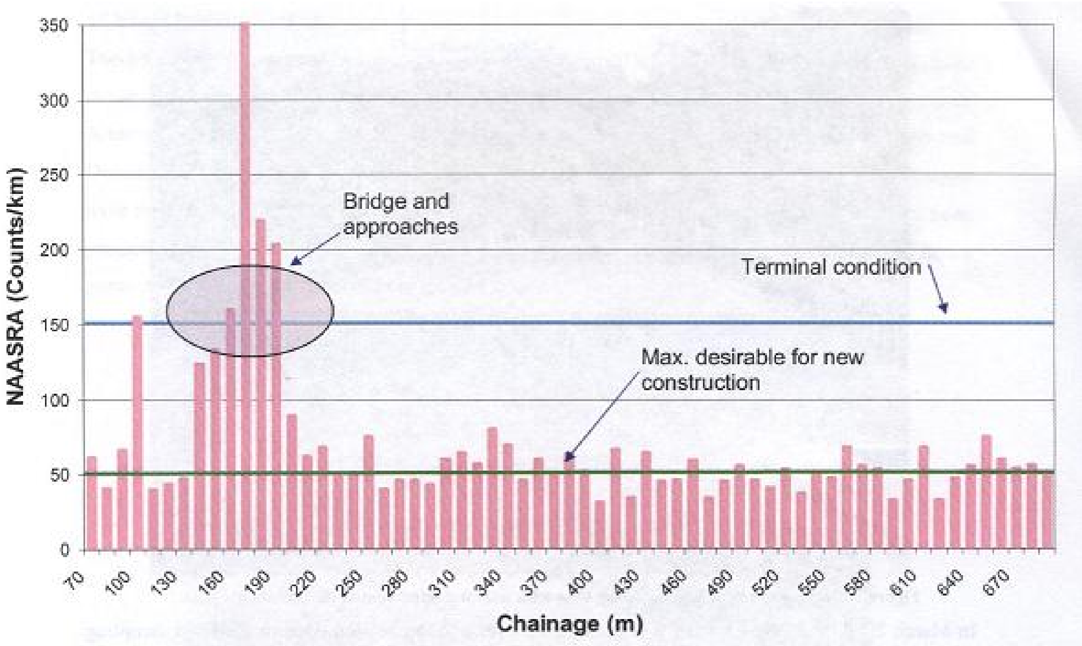

Figure 7.4: Roughness count for the 10 terminal access road (Schaeffer 2007)

A case study closer to home was rehabilitation work on Stanley Street, Strathpine which was showing signs of fatigue despite being cement stabilised in the past. The recommendation for use of a Geogrid came from a personal meeting held with

Raad Jarjees – Senior Manager, Infrastructure Delivery (North)

Kevin Prandolini – Coordinator Project Construction (North)

A general discussion was held regarding the current technologies Moreton Bay Regional Council (MBRC) were embracing in order to overcome the problem of pavements on reactive subgrades. MBRC's subgrade problem is not the blacksoil of the ICC area, but is a highly reactive and dissolving red/orange clay. Kevin best described it as like "toothpaste". Also searching for alternate ways of constructing pavement, they indicated successful trials of a Geogrid called Tensar, used on Stanley Street Strathpine.

Stanley St is typical of the older streets in the area, over the years it has had kerb and channel added to one side by a developer, using a pavement type that was incompatible with the existing pavement, which has resulted in severe longitudinal cracking at the join between pavements allowing water ingress into the pavement and subgrade and the resulting multiple pavement failures. It had been rehabilitated at some stage in the past with cement stabilisation, and under that the subgrade had a CBR rating of 2.

Figure 7.5: Stanley Street, Strathpine (Google 2009)

The designed solution to the problem consisted of replacement of the existing pavement and subgrade down 590mm to handle the existing and future designed traffic volumes. As it was a major through route an alternate method was chosen to minimise inconvenience to traffic.

The final design chosen consisted of a layer of Tensar Geogrid SS30 on top of the subgrade, 300mm of type 2.3 CTB and 50mm AC. After 3 years, the pavement is performing perfectly with no signs of any flaws.

The history of the Tensar product dates back to 1992 where the US Army Corps of Engineers undertook a trafficking trial for light aircraft pavements. They performed multiple trials using a 13 tonne wheel load over pavements with several types of reinforcement including a control granular pavement. The results are shown in the graph below.

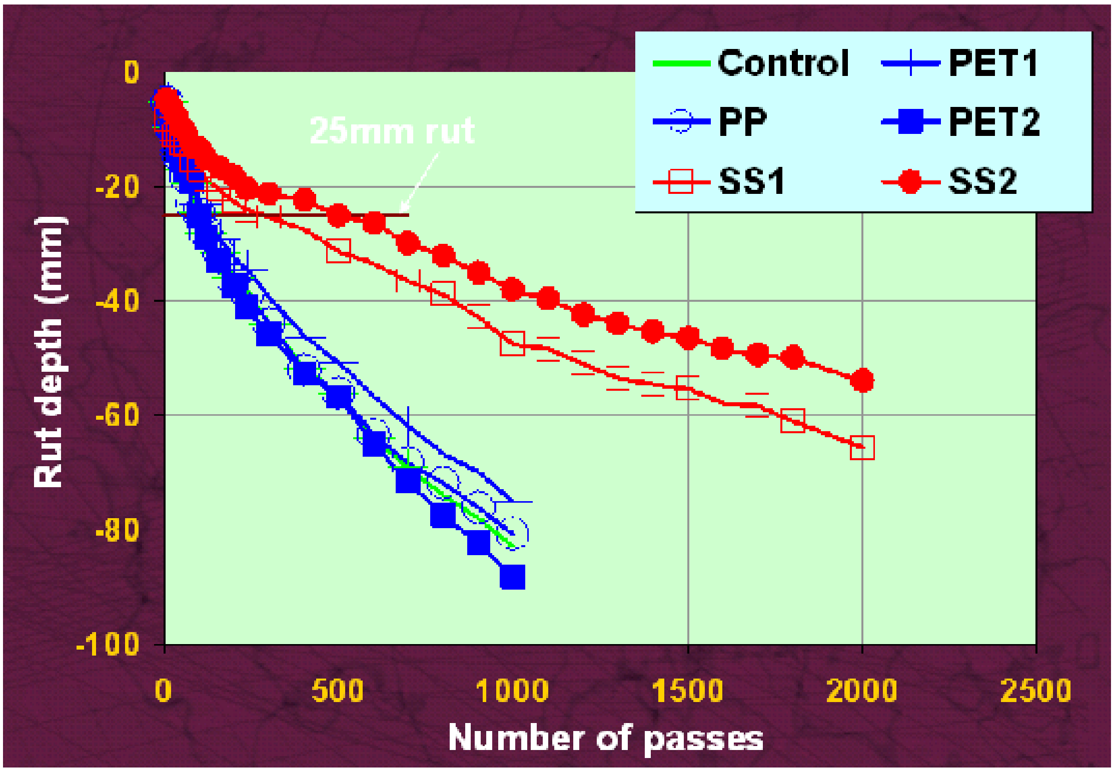

Figure 7.6: Results of USACE trafficking trials in 1992 (Geofabrics Australia 2009)

The results indicated significant differences in the pavement performances which was related to the properties of the Geogrid. They found that for the grid ribs, thicker and stiffer were better and a rectangular shape was better than round.

The technology works by transferring the point load received at the top of the gravel pavement to the geogrid at the bottom. Once there the confinement of the particles by the grid transfers the forces horizontally which is resisted by the strength of the grid and not transferred to the subgrade.

Figure 7.7: Snooker ball analogy of point load gravel forces.

The layer of geogrid has the potential to save a full pavement layer of gravel for subgrade CBRs 3 and under, which has a direct impact on the requirement to relocate underground services, as well as saving the cost of extra excavation and pavement layers. A full cost analysis for this technology is undertaken in chapter 8.

Figure 7.8: Thickness comparison of Geogrids to gravel (Geofabrics Australia 2009)

7.3 Mass Foam Blocks

A product not seen at all in Australia, but used extensively in Europe is the use of mass foam blocks or expanded polystyrene. Used as early as 1960, the Norwegian Road Research Laboratory routinely uses the polystyrene for road insulation, where around 50,000 m^3 of foam block are used annually. The concept is that the polystyrene, used in a relatively shallow excavation, topped with a slab of structural concrete, could correct sinking pavements and failing embankments at significant savings over conventional methods. The block size used are approximately 4.8 meters long, 1 meter wide and 1.2 meters high.

Conventional gravel pavements use multiple layers of gravel to dissipate the traffic load by the time it reaches the subgrade level, however over swamp and peat laden subgrades, the additional weight only leads to additional settlement of the subgrade. The polystyrene is a lightweight material and reduces the load on the subsoil.

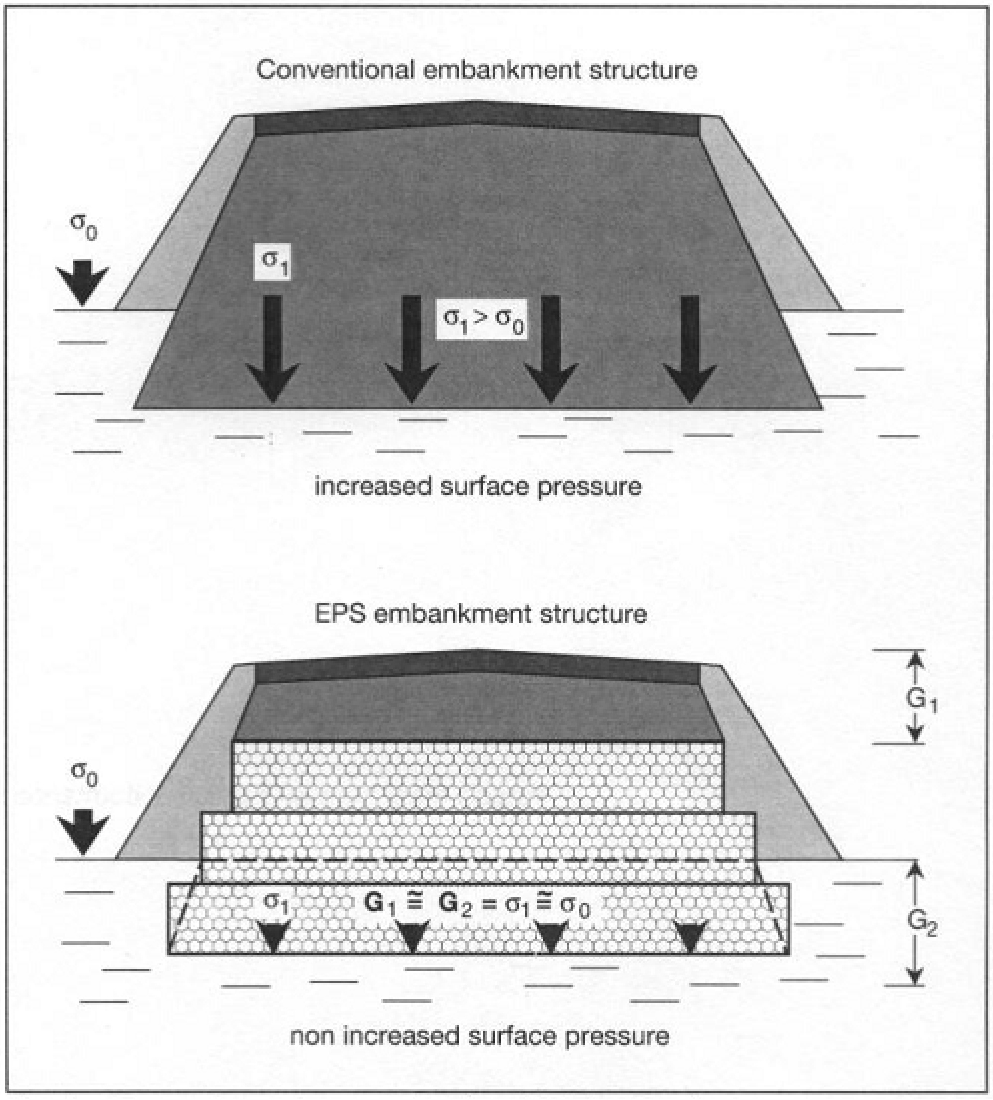

Figure 7.9: Comparison of gravel and polystyrene loads on subgrade (Styropor – Highway Construction/ Ground insulation.)

Properties of mass foam blocks in sub base situations:

- Sustain loads of up to 5 ton per square meter
- Lightweight , 20 kg / m^3
- Resistant to chemical attacks from salts and alkalis
- Does not rot or turn mouldy
- Burrowing animals can damage it but it is not favourable habitat
- Savings of up to 50% over conventional gravel pavements, not from supply of material, but on transport / hauling costs and placing.

The technology has various areas of application: (Styropor – Highway Construction/ Ground insulation.)

- Substructure on low CBR subgrades to reduce the load.
- Backfill at abutments to reduce the horizontal earth pressures and differential settlement at abutment
- Reconstruction of embankment failures and slides

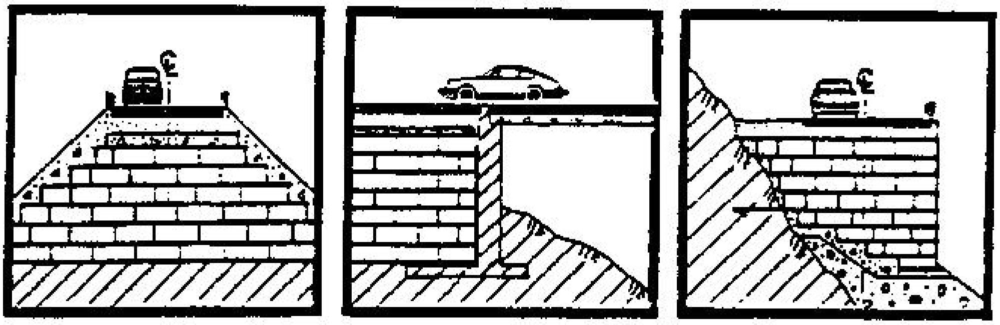

Figure 7.10: Polystyrene uses (Styropor – Highway Construction/ Ground insulation.)

After the 1985 international road building conference in Oslo, various other countries looked favourably at the advantages of mass foam blocks, such as Holland, France, Germany, USA, Canada and Japan. Use of the block in Japan has seen enormous growth in the late 1980s, however to date no information exists on the use of the block in Australian conditions.

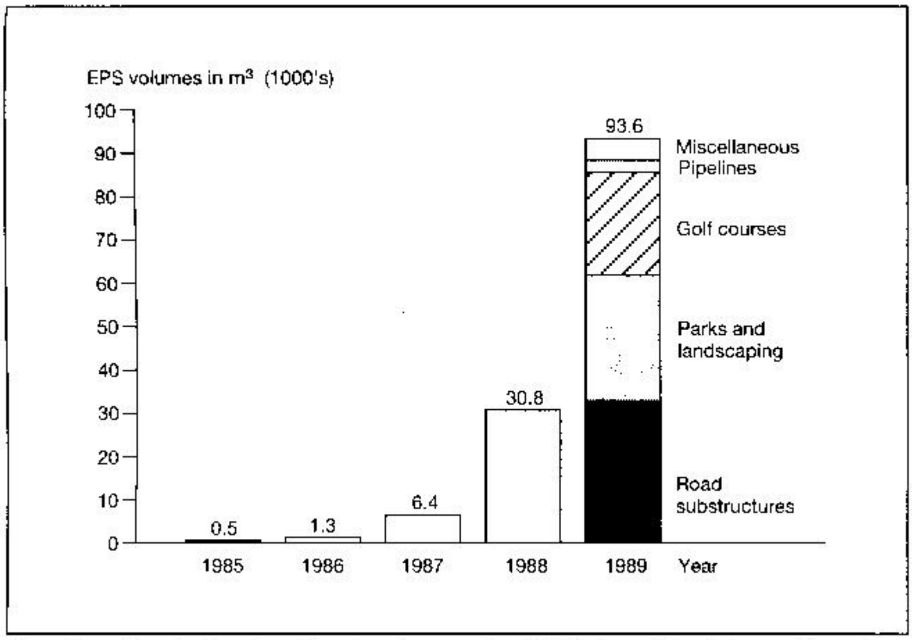

Figure 7.11: Use of foam blocks in Japanese earthworks projects (Styropor – Highway Construction/ Ground insulation.)

7.4 Full Asphalt Pavements

There is a general resistance within ICC to do full depth asphalt pavements despite their use on all the highways surrounding Ipswich. It is thought that this may be due to the difficulty in rehabilitating the pavement in the future. A recent job on Blackstone Road was as close as ICC has come to full depth asphalt. The pavement was experiencing cracking and rutting due to the volume of traffic using it. The solution was to profile the road down 200mm, replace the pavement with 150mm deep lift and 50mm asphalt wearing surface. However, as the pavement is still relying on underlying gravel layers, it cannot be considered a full depth asphalt pavement.

Figure 7.12: Blackstone Road Silkstone rehabilitation by deep lift asphalt

Pavement requirements are calculated the same as any typical gravel pavement, with subgrade conditions and estimated traffic pattern determining the required depth of full asphalt. A typical design chart has been included in appendix G.

Comparison between the gravel and asphalt pavements for a typical Ipswich collector road with 1 * 10^6 ESA reveals a 590mm gravel pavement compared to a 275mm asphalt pavement, so considerable saving of time and excavation are possible.

Advantages of Asphalt Bases (The Asphalt Institute 1981)

- Asphalt bases resist pavement stresses better than aggregate which has no tensile strength
- Asphalt bases give better riding quality
- Weather delays minimised
- Asphalt bases can be used by construction traffic
- Construction time is reduced
- Services relocation can be minimised due to thinner pavement requirements

- Asphalt is less effected by moisture ingress as gravel pavements are
- Construction work is can be staged and built in several layers :
    - Final layer is not required until traffic volume warrants it
    - Deficiencies in subgrade or base will show up under traffic and can be repaired before final layer applied
    - Budgetary restrictions allowed for until ultimate design
    - Can built for shorter time span until traffic increases
    - Overlaid pavements perform better when trafficked than equivalent new pavements

With the availability of asphalt and contractor to lay it, compared to the lack of availability of final trim grader operators, full depth asphalt pavements should be considered more seriously.

7.5 Other innovative Australian Pavements

7.5.1 400mm deep stabilisation.

Standard stabilisation is usually performed to depths of 250mm. A single layer 400mm stabilisation was used in South Australia for the first time in 1993 on the Sturt highway. It was the latest technology machine to achieve this depth. Similarly 360mm + stabilisation occurred in Cooma NSW in 94. The Council found that the cost was significantly lower than that previously adopted for granular overlays. *(Austroads, 1995)*

7.5.2 Stabilisation of just the outer wheel path

A trial in Queensland used stabilisation in just the outer wheel path on 13 kilometers of roads around Warwick. They found the cost to be $9 to $12 m2. *(Austroads, 1995)*

7.5.3 Crushed Glass Pavement additives

The Alex Fraser Group in Laverton in partnership with Sustainability Victoria is currently undergoing trials to the suitability of crushed glass as an additive in Class 3 and 4 sub base materials. The group intends to set up 10 trials to compare different proportions of the road base mixed with crushed glass. If successful, the use of crushed glass could divert over 100,000 tonnes of glass from landfill each year and saving the dwindling supply of good pavement gravels. The trials are due for completion in May 2011 at a cost of $676,764. (Glass in road base trial,2009)

7.5.4 Fibredec spray seals

Fibredec spray seals to control cracking , polymer modified bitumen emulsion, used extensively throughout Europe, now being trialled in South Australia by the Department of Transport to control cracking, also being used by four councils in Western Australia. In mid 1994, Queensland Transport trialled Fibredec on 5 highways around Brisbane.

Using Fibredec over sub grade as an in-situ blanket strengthening layer, proved less expensive than geotextiles. *(Austroads, 1995)*

7.5.5 Polyroad

Trials were undertaken in late 2000 on the Winton – Hughenden highway in Queensland with a product called Polyroad. The insitu base material used in the original highway was a very sandy material that lacked cohesion, which lead to failures such as rutting and shoving. With a lack of fines in the base, it was proposed to mix some of the subgrade blacksoil to improve the grading, however being mindful of avoiding high swell characteristics. The Polyroad additive was incorporated in the mix to make the clay particles hydrophobic while still having some lubricating properties to allow for compaction. To date the pavement has performed well. (Atkinson 2004)

7.5.6 Geotextile seals

An innovative technique being trialled in the Northern territory in black soil areas is to compact the blacksoil , seal , lay geotextile and then a second seal coat. This effectively controls the moisture in the blacksoil which performs reasonable well without moisture variation. This technique is useful in this area due to the lack of gravels available in this area. Also trialled in Western NSW in 1985 and at Brewarrina in 1991. They found the benefits were –

- Improved amenities for remote rural communities
- Substantial reduction in the use of scarce gravels
- Elimination of dust problems
- Improved road safety and vehicle wear

However they have found the useful life to be only 5 to 8 years for this technique. *(Austroads, 1995)*

7.5.7 Stabilisation with Cationic Slow Setting bituminous emulsion

Trial in the Northern Territory in 1992 along 2.86kms of the Stuart Highway used Cationic slow setting bitumen emulsion for pavement stabilisation. They compared the trial to conventional stabilisation techniques in the opposing lane. After 2 years they found that the emulsion stabilisation appeared more solid with a tightly bound surface which makes it more resistant to traffic and moisture ingress. *(Austroads, 1995)*

7.5.8 Plastic sheet over Blacksoil

In 1971 a section of the Carpentaria Highway was rehabilitated by using a plastic membrane to stop moisture loss from the subgrade. They found the cost of the plastic method to be 109% higher than normal methods, but believed this would be more than offset by the maintenance work required to maintain the pavement. The most difficult part was placing gravel over the laid plastic, as a grader could damage the plastic with the blade. They found that using scrapers to dump a thick layer over the plastic was effective, followed by a grader to trim to the required depth. *(Austroads, 1995)*

Chapter 8 – Costs comparisons of alternate solutions

To realise the benefits of the alternate technologies discussed, an analysis was undertaken of the alternates against the standard full depth gravel treatment.

To protect Council's commercial in-confidence unit rates, approximate pavement areas are quoted, which gives the reader a feel for the general size of the project undertaken.

8.1 Foam Bitumen

8.1.1 Case Study – Redbank Plains Road

Redbank Plains Road is a major collector road for traffic from the Redbank Plains area heading towards the southern suburbs of Brisbane. The pavement that was rehabilitated was a section from Kruger Pde to Frangipanni St . This section was originally constructed in 1994 under contract to Main Roads as one of Councils first construction jobs in a quality assured environment. This road has since been handed back to Council control.

At the time of construction Council was constructing a large portion of their program under contract to Brisbane City Works (BCW), as the Ipswich resources were tied up on several multi million dollar long term projects. Ipswich Council had relatively little experience with the use of foamed bitumen works, so took the opportunity to use BCW's experience on the works.

Rehabilitation area was in excess of 10,000 square metres.

Foamtec – Integrated Pavement Solutions cost to do the work (gravel components only, not including AC seal, on costs etc):

- Bitumen foam stabilise existing pavement: $624,000
- Establishment / disestablishment costs: $8,500
- Conditions: Council to establish a stockpile site nearby. Cost: $15,000

Total estimate: $647,500

Timeframe: 15 days on site, to remove, treat and relay pavement 225mm deep.

Actual costs for the pavement rehabilitation works were $986,212, and the increase was due to a large soft area found in the subgrade after excavation of the base.

Figure 8.1: Soft subgrade on Redbank Plains Road

This area was treated by rockfill to bridge the soft area. This is a compeling reason to use the ex-situ method of foam bitumen stabilisation, as if the work was done in-situ, it may have gone undetected and failed at a later date.

Figure 8.2. Rock stabilisation of soft subgrade

A comparison was made at the time using conventional full depth pavement design which required a pavement thickness of 760mm.

- Excavation of existing pavement to spoil (9726 m3): $468,403
- Supply and place unbound gravel: $1,332,736
- 4 traffic controllers and signage ute for 72 days: $144,331
- Water filled barriers due to the depth of construction: $27,809
- Lowering of water services believed to be at only 600mm depth: $unknown

Total estimate: $1,973,279

Realised savings are $987,067, however I would suggest that this case study is in the extreme regarding the size of the project and the equivalent gravel pavement required, and the 50% saving should be taken in context. The 2nd case study is a more typical example of a rehabilitation project that Council undertakes.

Figure 8.3: Foam bitumen treatment on Redbank Plains Road before wearing course

8.1.2 Case Study – Pine St Flinders View

Pine St Flinders View was previously seen in chapter 5 with the decision being made to perform a minimal treatment, however as quotes were sought for foam bitumen stabilisation of the street, it is a relatively simple exercise to do a direct comparison between the three methods: full granular, foam bitumen and cement stabilisation.

Full depth granular pavement

- Excavation of existing pavement to spoil : $54,120
- Supply and place 550mm of unbound gravel: $103,730
- Primerseal and asphalt surfacing: $27,932

Total estimate: $185,782

Note: Telstra and several water crossing would have to be relocated if full depth gravel pavement was used.

Foam Bitumen

- Stabilisation of pavement ex situ: $66,092
- Establishment costs: $10,000
- Asphalt wearing course (no primerseal): $23,926

Total estimate: $100,018

Cement Stabilisation

- Remove existing wearing course to spoil: $10,000
- Cement stabilise existing pavement: $12,100
- Primerseal and asphalt surfacing: $27,932

Total estimate: $50,032

It is obvious why the decision to cement stabilise was taken given the significant difference in costs for this method, however, to reiterate the findings in chapter 5, the method chosen is based on the experience of the rehabilitation manager and is a calculated risk to restore the pavement to a usable condition.

The important comparison is between the foam bitumen stabilisation and the gravel pavement, as both methods come from design charts for the full 20 year life of the pavement. Potential savings are $85,764 or 45% of the pavement cost.

8.2 Geosynthetics

8.2.1 Case Study – Spengler St East Ipswich

Spengler St East Ipswich is a local collector carrying a traffic load of about $2 * 10^5$ ESAs and is founded in blacksoil with a rating of CBR 2. This project started in April 2009 with a gas contractor laying a new gas main up the western side of the road to make redundant the nine gas crossing under the pavement which were located about 350mm from beneath the existing surface. The actual construction work began in early May 2009, with excavation to subgrade of about 450mm. The project soon experienced delays as a still active gas crossing was broken by the excavator, which had not been replaced in the initial works. It was not long after the project got underway again, when South East Queensland experienced a significant flood event in mid May and with a significant proportion of the blacksoil subgrade exposed, the Council had difficulties in making the street trafficable for residents access.

To make a fair comparison with the alternate technology, figures from the estimate will be used, not including the actual costs due to rain delays etc. Other possible savings are then noted after the direct comparison. Only the relavent pavement components of the estimate are used, as the alternate pavement proposed has no bearing on drainage or kerb costs.

Full depth gravel

Pavement design as constructed was 140mm of type 2.5 gravel, 140mm of type 2.4 gravel, 140mm of type 2.2 gravel and a wearing course of 30mm AC.

- Relocation of gas services: $44,365
- Excavation to spoil: $27,238
- Lower Subbase: $16,200
- Upper Subbase: $27,000
- Base: $21,700
- Surfacing Costs: $20,167

Total pavement related cost $156,670

Geogrid enhanced

Based on the recommendation from Geogrid supplier, savings on pavement layers can be made by adding Geogrid as a reinforced subbase layer. The new recommended pavement design becomes: a single layer of geogrid, 150mm of type 2.4 gravel, 100mm of type 2.2 gravel and 30mm of AC wearing course.

- Relocation of gas services: $0 (no longer required)
- Excavation to spoil: $22,500
- Layer of Geogrid: $7,750
- Subbase: $27,852
- Base: $20,256
- Surfacing Costs: $20,167

Total pavement related costs $98,525

In this case, if Council used the alternate Geogrid technology, they would have realised a significant saving of $58,145 or about 37% of the pavement cost, however, more importantly, there could have been significant time savings with the use of the alternate.

- The reduction in excavation depth would remove the requirement for gas service relocation, and while the majority of work was done before the crew attended site, the missed service created additional delays for the crew.
- The excavation reduction may also have moved the job forward enough that the geogrid and subsequent subbase layer may have been in place before the flood event occurred, thus saving significant time in waiting for the subgrade to dry out, and saving effort in trying to get residents into their homes.
- A definite time saving would be realised with a shallower excavation in spending less time daily installing and removing temporary driveway each morning and night giving residents access to their properties.
- Further indirect / overhead savings would be realised by the reduced timeframe like, Engineers time, admininistration overheads, site supervision etc.

If these savings were also costed into the alternate technology equation, then we could see the project saving approach 50%.Other than these time related costs, also to be considered is the cost to the community and residents. How do you put a price on the peace and quiet that the residents will enjoy by having the project finish a week or two earlier?

8.2.2 Case Study – Cedar Road Redbank Plains

Cedar Rd Redbank Plains is a collector road carrying $1*10^6$ ESA's and is founded in some of the worst blacksoil in the Ipswich area. The design CBR for the subgrade is rated at 2. In this case, there were no underground services to relocate, however, the significant depth of construction meant that a proportion of the day would be lost to creating ramps into and out of the excavation for through traffic and creating access to the residents that adjoin the construction.

Full depth gravel pavement

Several options were considered for pavement rehabilitation, and the design issued for construction was: 300mm of CBR10 subgrade replacement, 125mm of type 2.4 gravel, 125mm of type 2.3 gravel, 125mm of type 2.1 gravel, a primerseal and 40mm of DG14 AC wearing course. Estimated costs were

- Excavation to spoil: $44,800
- Subgrade replacement layer: $36,850
- Lower subbase: $17,867
- Upper subbase: $19,487
- Base: $19,764
- Surfacing: $42,189

Total pavement related cost $180,957

Geogrid enhanced

Once again, a recommendation was sought from the geogrid supplier and the revised pavement to handle the exact same axle count was: a layer of geogrid, 150mm of type 2.4 gravel, 150mm of type 2.3 gravel, 125mm of type 2.1 gravel, a primerseal and 40mm of DG14 AC wearing course. The revised pavement costs are:

- Excavation to spoil: $29,550
- Layer of geogrid: $9,255
- Lower subbase: $16,400
- Upper subbase: $18,040
- Base: $19,764
- Surfacing: $42,189

Total pavement related cost $135,198

The expected savings related to the use of the geogrid technology is $45,759 or about 25% of the pavement related costs. Once again the time factors are of significant importance to the Council, as the rehabilitation works requires a complete road closure and detours for the local residents, and the ability to save over a week in construction time cannot be underestimated. As a practical measure of the savings that could be realised, permission was sought to undertake a trial of the geogrid technology on this road in mid September 2009. A business case was required and supplied to the project services manager and the engineering services manager. The business case was approved and the trial proceeded as planned. The business case is shown in Appendix H.

Due to the alternate treatment of the pavement layers, the project progressed faster than anyone predicted and there were no photos recorded of the actual pavement treatment. The reduced scope in excavation saw this activity being completed in only 3 days. The Geogrid was laid in a few hours and the lower sub base was placed the same day. By the time this researcher was informed the trial was in progress, the upper sub base layer was being laid and compacted for kerb the following day.

Total time for the road closure was 3 weeks compared to the original estimate of 6 weeks for the full granular pavement design. This is a significant saving of disruption to the local residents, as the detour was a very roundabout route. As expected with time savings comes financial savings. To date the forecast final cost for this project is $150 000 under budget allocation. The majority of savings can be attributed to the saving in pavement costs, however other savings were also realised in traffic control and general overhead costs.

Council intends to use some of the savings for physical testing and yearly monitoring of the pavement performance in order to make a better informed decision surrounding this product in the future.

Chapter 9 – Recommendations and Conclusion

Aims / Objectives and Recommendations

One of the major aims of this dissertation was to analyse the alternate methods that Ipswich City Council has been performing over 40 years. Some methods have been successful whilst others have given useful lives as low as 5 years. This dissertation delved into those successes and failures and came up with a range of recommendations and improvements to the existing processes to ensure a higher rate of success. Some of the minor recommendations noted were:

- Only used controlled copies of the Austroads and Main Roads pavement manuals to ensure current information is used.
- Electronically capture the former ICC pavement manual to avoid a total loss of this valuable document.
- Have the current project managers use the knowledge gained in the past by Bob Gamble in his Ipswich specific paper on stabilisation techniques.
- Avoid the use of lean mix where possible, however, if required, use a geofabric interlayer to reduce reflective cracking.
- Use 2 coat bitumen seals on cement stabilisation in preference to asphalt.
- Trial the use of a bobcat based grader for small gravel pavements.

The major recommendations and main object of this paper was the investigation and analysis of alternate methods of: geosynthetics, full depth asphalt pavements and foamed bitumen stabilisation. All methods were investigated in depth, with case studies showing that significant savings were possible by using the alternates. In the case of the geosynthetic, the physical trial of the product showed an actual saving in the order of $150,000.

Further work

The work of this dissertation can be extended further as only time and traffic impact on the pavement can show up the long term effects of the alternate methods.

- An in-depth study should be performed on the method of stepping the boxed excavation for lean mix pavements and the success of interlayers.

- The physical trial on Cedar Rd could be tested for deflection every year to determine the expected life of the pavement.
- Investigate and trial polymer modified seals on cement stabilisation works to minimise reflective cracking.

If the work of this dissertation is to be applied to other subgrade types, then further analysis of mass foam blocks should be undertaken, as it has proved itself world wide.

Conclusion

Alternate pavement types have existed for many years and are used by other local authorities and the state Main Roads department. Council have not maximised the opportunity to save budget and scarce gravel resources by continuing to use methods that have been historically popular, despite some of the methods failing after only a quarter of their predicted life. The alternate technologies offer Council the chance to produce the same result in a faster, smarter and more efficient manner, and, as they are essentially spending the public purse, this should be the goal for any local authority.

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Appendix A – Project Specification

University of Southern Queensland

FACULTY OF ENGINEERING AND SURVEYING

ENG4111/4112 Research Project
PROJECT SPECIFICATION

FOR: Jeff CRONE

TOPIC: ALTERNATE PAVEMENT TYPES ON REACTIVE SOILS IN THE IPSWICH COUNCIL AREA

SUPERVISOR: Associate Professor Ron Ayers

PROJECT AIM: To analyse the success of different pavements types used on reactive soils in the Ipswich Area, investigate new methods not currently used by Council and recommend the best value for money pavement type for the future.

PROGRAMME:

1) Carry out a literature study, which identifies the problems encountered in designing, building and maintaining roads on reactive soil subgrades.

2) Investigate and document the different pavement types previously used by Ipswich City Council (ICC) and the problems that have been encountered from reactive soil subgrade effects on these road pavement types.

3) Analyse the methods that determine the current practices and the accuracy of how decisions are made regarding the gravel depth or use of lean mix / no fines concretes.

4) Select a number of roads which have been designed and built on reactive subgrades using current practices. Analyse the success and/or failures (causes/extent) on these roads.

5) Investigate possible alternate technologies, innovative solutions and methods not previously used at ICC and their success rates in other locations.

6) Make recommendations on the costs and benefits of using the alternate pavement technologies in ICC.

7) Report on the project in the required oral and written formats.

As time permits:

8) Trial new technologies and analyse the success of the trials

AGREED ______________ (student) ______________ (supervisor)
Date: 24/ 3/2009 Date: 31/ 3/2009

Examiner/Co-examiner: ______________
2/4/2009 2/4/09

Appendix B – ICC list of cement stabilisation jobs

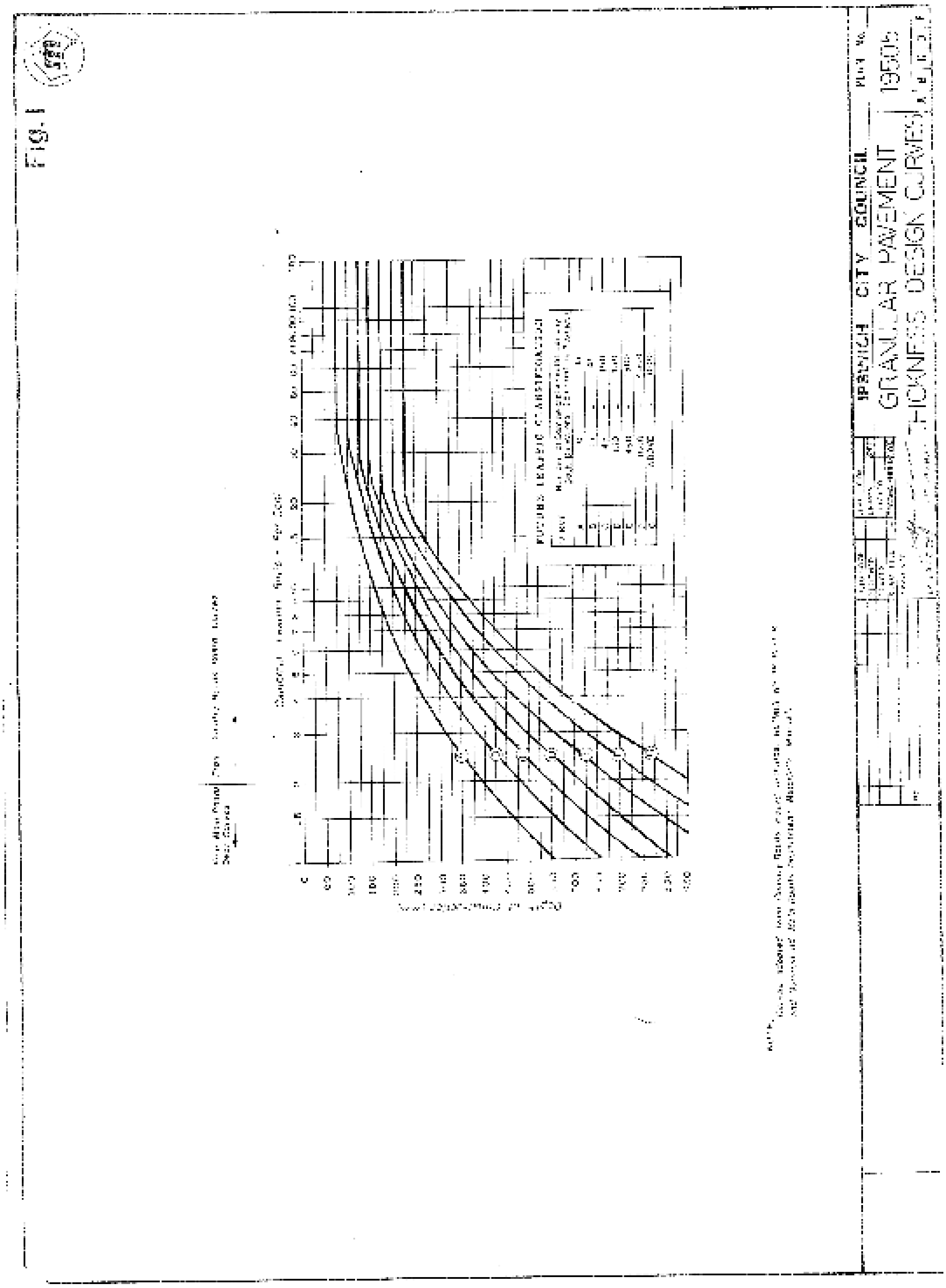
Road Name	Suburb	Treatment	Const Date	Seal Type	Traffic Count	Comment
Phillip St	Ebbw Vale	4% BG cement stabilisation of 150mm base	Early 2001	Prime and 2 coat bitumen	258 v/day	Lean mix seperation, cement stab cracking , incorrect crown, did not removing bulking at time of construction
Ross St	Ebbw Vale	Leanmix widening	???	25mm AC	134 v/day	massive failures occuring at join between leanmix and gravel
Mary St	Blackstone	3% cement in 150mm base	Late 1998	Prime and 2 coat bitumen	266 v/day	perfect condition for age, no cracking
Redbank Plains Rd	Redbank Plains	4% GB cement in 175mm base	Early 2003	Primerseal + 50mm AC	14003 v/day	multiple failures and cracking, needs urgent rehab
Cudgee St	Redbank Plains	Foam bitumen stabilisation	Early 2009	Primerseal + 50mm AC	356 v/day	generally good, small section of cracking, suspect insufficient pavement
Boscawan St	Bellbird Park	Lime stabilisation	Mid 2006	Primerseal + 50mm AC	na	Good condition, other than leanmix over gas line.
Brennan St	Bellbird Park	4% GB cement in 150mm base	Early 2001	Prime and 2 coat bitumen	1687 v/day	no cracking, however significant rutting in wheel path
Mitchell St	Riverview	3% cement in 200mm base	Early 1999	Prime and 2 coat bitumen	1444 v/day	perfect condition.
Margret St	Booval				na	full leanmix subbase, gravel over, severe cracking

Appendix C – ICC list of lime stabilisation jobs

LIME STABILISATION PROJECTS

Project	Suburb		Date	Remarks - Special comments
Rex Street	Eastern Heights	**Olmai Ave** to Grange Road	**1979**	Quicklime used **Plans Avail. 20527-20528**
Trumpy Street	Silkstone	**South Stn Rd.-Ch250**	**1978/79**	**Plans Avail. 11490**
Doyle Street	Silkstone	**Auld St. – End**	**1979**	**Plans Avail. 11602**
Bergins Hill Road	Bundamba	**Thompson St. - Herbert St**	**1976**	**Plans Avail. 20332**
Phyllis Street	Eastern Heights	**Phillis, Vivian, Edgar & Fredrick Sts done**	**1961**	**Plans Avail. 10393**
Vivian Street	Eastern Heights	**as one estate**		
Welsby Street	North Booval	Jacaranda Street to end(N)	**1979**	**Plans Avail. 20482**
Caithiness Street	North Booval	Welsby Street to North Station Road	**1979**	**Plans Avail. 20483**
Blackall Street	Basin Pocket	**Davidson Street** to Mc Gill Street	**1979**	**Plans Avail. 20523**
Chermside Road	Basin Pocket	Jacaranda Street to McGill Street	**1977**	**Plans Avail. 20377-79**
Robertson Road	Raceview	adjacent BP ??????		Bagged lime **(No Plans Available)**
Whitehill Road	Raceview	Edward Street to Cascade Street	1968/1990	This section was redone in 1990 - Plans available
Whitehill Road	Raceview	Cascade Street to Cemetery Road	1974	Plans available
Cascade Street	Raceview	Raceview Street to Wildey Street	1976	Plans available
Raceview Street	Raceview	Cemetery Road to Robertson Road	1974	Plans available
McGill Street	Basin Pocket	Blackall Street to Howard Street	1994/5	**No Plans Available**
Whitehill Road	Flinders View	Lance Drive to Kingston Drive (west side only)	1997	bagged lime + Parks rotavator **No Plans Avail.**
Bernadette Crescent	Rosewood	western leg from Casandra lane to No.77	1998	**No Plans Available**
Madden Lane	Rosewood	School Street to eastern end	**2001**	**Plans Available 98123.100**
Warrego Highway		adjacent Beduhns Road ??????????????		**No Plans Available**
Warrego Highway		Sundowner Hotel back towards Ipswich ????		**No Plans Available**
John Street		William Street to Skinner Street		**No Plans Available**
Karrabin Rosewood Road		Harwood/Elms Road towards Walloon		**No Plans Available**
McGill Street	**Basin Pocket**	**Blackall St - Chermside Rd**	**1979**	**Plans Available 20525**

Appendix D – Former "ICC" pavement design curves



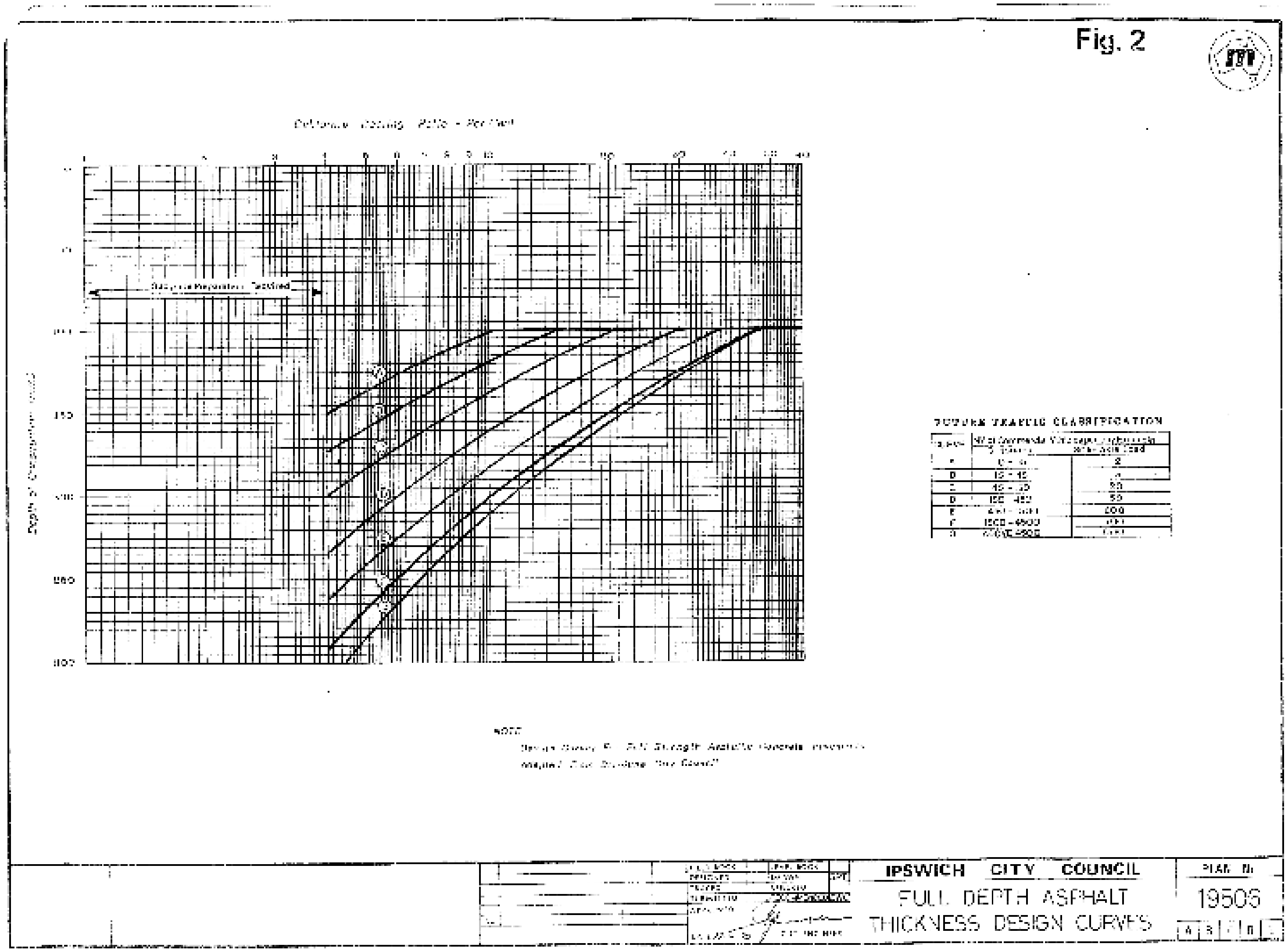
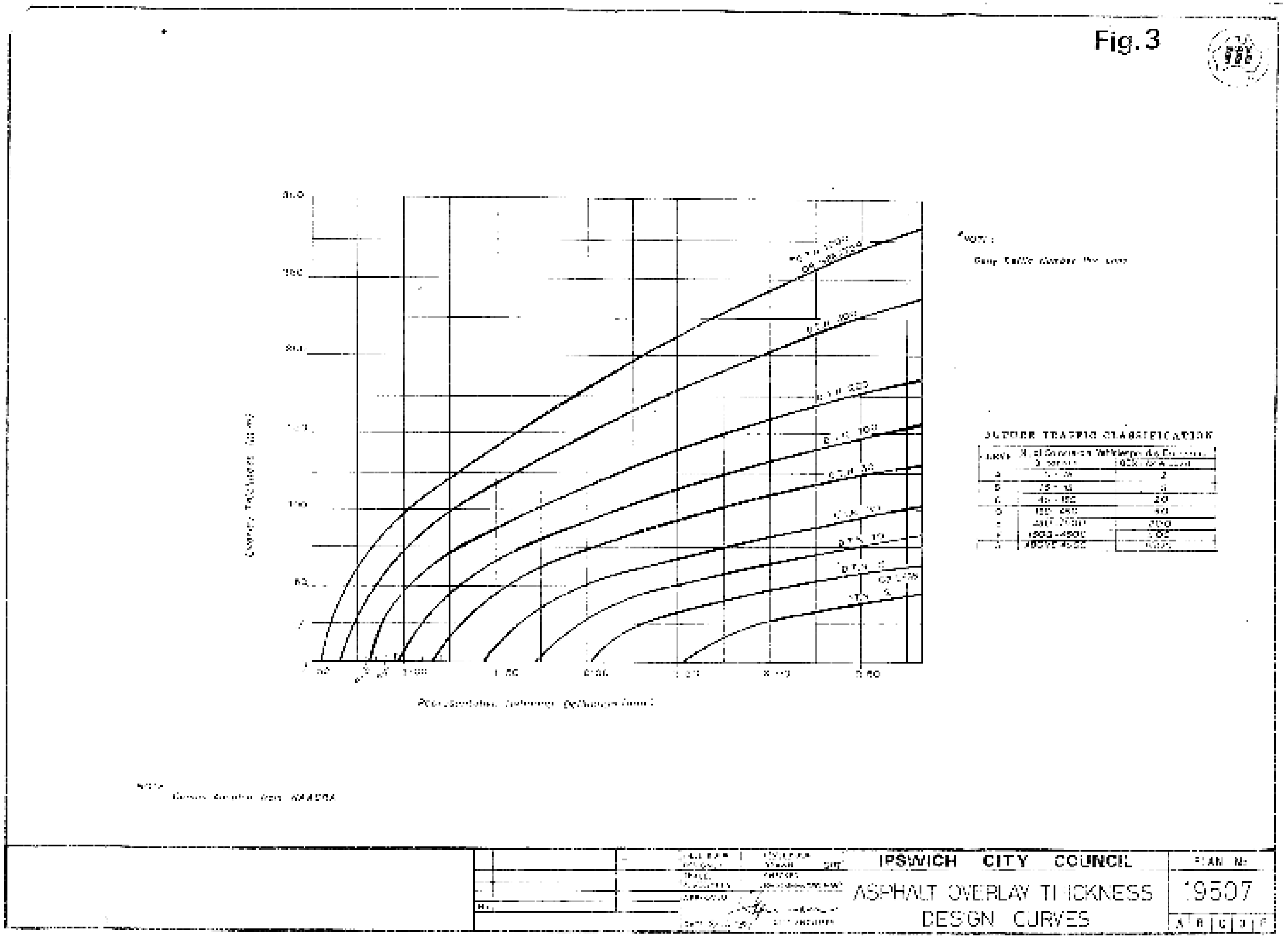


Fig. 2
IPSWICH CITY COUNCIL
FULL DEPTH ASPHALT
THICKNESS DESIGN CURVES
PLAN No
19506

Fig. 3


IPSWICH CITY COUNCIL
ASPHALT OVERLAY THICKNESS
DESIGN CURVES
PLAN No
19507

Appendix E - Investigation report, Pine St Flinders View

PROJECT: PINE STREET, FLINDERS VIEW

PROJECT No.: LR – 3194 – A8

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1. INTRODUCTION

In response to a request from Mr W Barram (Technical Officer – Infrastructure Planning), an investigation was carried out on PINE STREET, FLINDERS VIEW, to determine rehabilitation options for the existing pavement.

This report provides:-

- Comments on the existing conditions and nature of the subject section;
- Profiles of existing materials and evaluation of those materials from soil tests;
- Recommendation for Design C.B.R.;
- Options for rehabilitation of the existing pavement.

2. SCOPE

2.1 PROJECT

This project covers the rehabilitation of Pine Street between Hibiscus Street and Kurrajong Street.

2.2 TESTING

- To assess the existing subgrade in order to provide recommended Design C.B.R. values for pavement design considerations;
- To assess the depth and quality of the existing pavement materials for possible reuse.

3. INFORMATION PROVIDED

- Design options to be based on 2×10^5 ESAs.
- Chainage details obtained from Council's Pavement Management System.

4. SITE DESCRIPTION / HISTORY

Pine Street is a local collector road servicing a residential area of Flinders View. The subject section, constructed in the 1980s, consists of two lanes with kerb and channelling and is approximately 395 metres in length. Width averages 6.2 metres.

The road runs south - east from Hibiscus Street for most of its length before turning to the east where it connects with Kurrajong Street.

The terrain is relatively flat from Hibiscus Street to Gum Street before rising to Kurrajong Street.

A section of kerb (40 metres in length, commencing at Gum Street) has been replaced on the right hand side.

Traffic would include light passenger vehicles and service vehicles.

5. TESTING PERFORMED

Profiles of existing pavement and natural materials;
Moisture Content of existing pavement;
Quality of existing pavement materials;
Soaked C.B.R. rating of existing pavement;
Subgrade insitu C.B.R. (D.C.P. test);
Insitu moisture content of natural materials;
Assessment / classification of existing natural materials;
Soaked C.B.R. rating of predominate subgrade materials.

6. ATTACHMENTS

Test Summary Report;
Profile Summary Report;
Soaked C.B.R. reports;
Site Location Plan

7. FIELD WORK FINDINGS

7.1 OBSERVATIONS IN SUBJECT SECTION

The pavement is exhibiting signs of distress with craze, longitudinal, transverse and diagonal cracking, minor rutting, minor deformation, potholing, major areas of pavement repair, subsidence and joint cracking along stormwater trenches which are located in the pavement as evidence of this. The existing kerb and channelling is cracked but has not deformed with volume change in the subgrade.

The predominate area of pavement distress is between Hibiscus Street and Gum Street.

7.2 SEAL

The seal in the subject section is a bitumen seal approximately 20mm in depth. The road was resealed in 1994 with a 10mm seal.

7.3 PAVEMENT

The existing pavement was found to consist of soil aggregate gravel, sourced from the former Wood's Pit.

This gravel meets specification requirements for Type 2.4 and "C" grading requirements. The gravel has a Soaked C.B.R. rating of 56.

The total pavement thickness along the subject section varies between 280mm and 380mm with an average thickness of 330mm.

The pavement appears to have been constructed to two separate depths, according to different subgrade types.

Pavement distress could be attributed to:
- Inadequate quality of pavement material;
- Volume changes in subgrade;
- Moisture ingress and movement through pavement and subgrade;
- Settlement near manholes and along trench lines;
- Fatigue of pavement and age of seal;
- Seal hardening;
- Inadequate base course.

7.4 SUBGRADE

The road could be divided into two basic subgrade types of high plasticity clay and medium plasticity silty clay with a classifications of CH and OH respectively:

- **SECTION 1:** Chainage 0 to Chainage 220
- **SECTION 2:** Chainage 220 to Chainage 395 (although the kerb has

cracked, the pavement is not displaying the same amount of distress as that in Section 1).

Good comparisons between Soaked, Estimated and Insitu C.B.R. values were obtained.

SECTION	**1**	**2**
C.B.R. METHOD	**C.B.R. VALUE / RANGE**	
INSITU TESTING (D.C.P.)	2.5 to 30	15 to 60
10% ILE VALUE	2.0	5.0
ESTIMATED VALUES	1.5 to 3.0	8.0 & 11
SOAKED VALUE	1.5	No result

8. COMMENTS/RECOMMENDATIONS

8.1 DESIGN C.B.R.

Design C.B.R. values are recommended as follows:

- **Section 1: 2.0**
- **Section 2: 10**

Both recommendations are based on good correlations of soaked, estimated, insitu and 10%ile values.

8.2 DESIGN OPTIONS

Design options are provided using the former Ipswich City Council's Flexible Pavement Design Manual and the Queensland Department of Main Roads Design Manual.

Options are provided to consider full reconstruction options as a base for comparisons.

FORMER IPSWICH CITY COUNCIL'S FLEXIBLE PAVEMENT DESIGN MANUAL - USING CURVE "C"

DESIGN C.B.R.	2.0	10
FLEXIBLE PAVEMENT	545mm	225mm

QUEENSLAND DEPARTMENT OF MAIN ROADS DESIGN MANUAL

(FULL DEPTH GRANULAR)

NOTE: Where subgrade C.B.R. values are less than 3.0, subgrade replacement or subgrade treatment is recommended. A Design C.B.R. of 3.0 is then used for final design purposes.

DESIGN C.B.R.	2.0	10
NORMAL DESIGN STANDARD with STANDARD SPECIFICATION BASE		
PAVEMENT - INCLUDES IMPROVED SUBGRADE LAYER OF 150 mm for C.B.R. of 2.0	550mm	235mm
SECOND DESIGN STANDARD with STANDARD SPECIFICATION BASE		
PAVEMENT - INCLUDES IMPROVED SUBGRADE LAYER OF 150 mm for C.B.R. of 2.0	510mm	210mm

QUEENSLAND DEPARTMENT OF MAIN ROADS DESIGN MANUAL

(CATEGORY 2 CEMENT TREATED PAVEMENT)

DESIGN C.B.R.	2.0	10
BITUMEN SEAL		
CEMENT TREATED PAVEMENT	395mm	340mm
ASPHALT	40mm	40mm
CEMENT TREATED PAVEMENT	335mm	280mm

OTHER OPTIONS

DESIGN C.B.R.	2.0	10
ASPHALT	40mm	40mm
UNBOUND PAVEMENT	425mm	270mm
ASPHALT	40mm	40mm
UNBOUND BASE COURSE	125mm	125mm
CEMENT TREATED SUBBASE (CATEGORY 2)	165mm	100mm

8.3 ISSUES and CONSIDERATIONS

- DEPTH OF EXISTING PAVEMENT IS INSUFFICIENT FOR CURRENT DESIGN REQUIREMENTS FOR FULL DEPTH UNBOUND PAVEMENTS.
- CONSTRUCTION WILL BE UNDER TRAFFIC
- ACCESS FOR RESIDENTS TO BE MAINTAINED
- REACTIVE NATURE OF SUBGRADE POSES MAIN PROBLEM.
- KERB AND CHANNEL SHOULD BE REPLACED AS CRACKS WILL ALLOW MOISTURE INGRESS TO PAVEMENT.
- TREATED PAVEMENTS WILL CRACK WITH MOVEMENT IN SUBGRADE DUE TO VOLUME CHANGES.
- AS PAVEMENT BETWEEN CHAINAGE 220 AND CHAINAGE 395 HAS NOT FAILED TO SAME EXTENT AS FIRST 220 METRES, CONSIDER RETAINING EXISTING PAVEMENT WITH REPLACEMENT OF KERB AND CHANNELLING

8.4 OPTIONS

8.4.1 TREATMENT OF EXISTING PAVEMENT:

OPTION 1

TREAT PAVEMENT WITH 3.0% F.A.B. CEMENT FOR DEPTH OF 200mm

BITUMEN SEAL

OPTION 2

REMOVE 165mm OF EXISTING PAVEMENT

TREAT REMAINING PAVEMENT WITH 3.0% F.A.B. CEMENT FOR DEPTH OF 150mm

PLACE BASE COURSE (TYPE 2.2 – C.B.R. 60) 125mm

ASPHALT SEAL 40mm

8.4.2 RETAIN PAVEMENT FOR SECTION CHAINAGE 220 – CHAINAGE 395:

PROFILE FLANKS TO REMOVE EXISTING KERB – DEPTH OF 290mm

LEAN-MIX CONCRETE SUBBASE FOR KERB: 125mm

TREAT PAVEMENT WITH 3.0% F.A.B. CEMENT FOR DEPTH OF 150mm

ASPHALT SEAL & OVERLAY: 40mm

8.4.3 ALL OPTIONS SHOULD INCLUDE THE PROVISION OF NEW KERB AND CHANNELLING.

THIS REPORT PREPARED BY

PAUL COKER

TEMPORARY REHABILITATION PROJECTS OFFICER

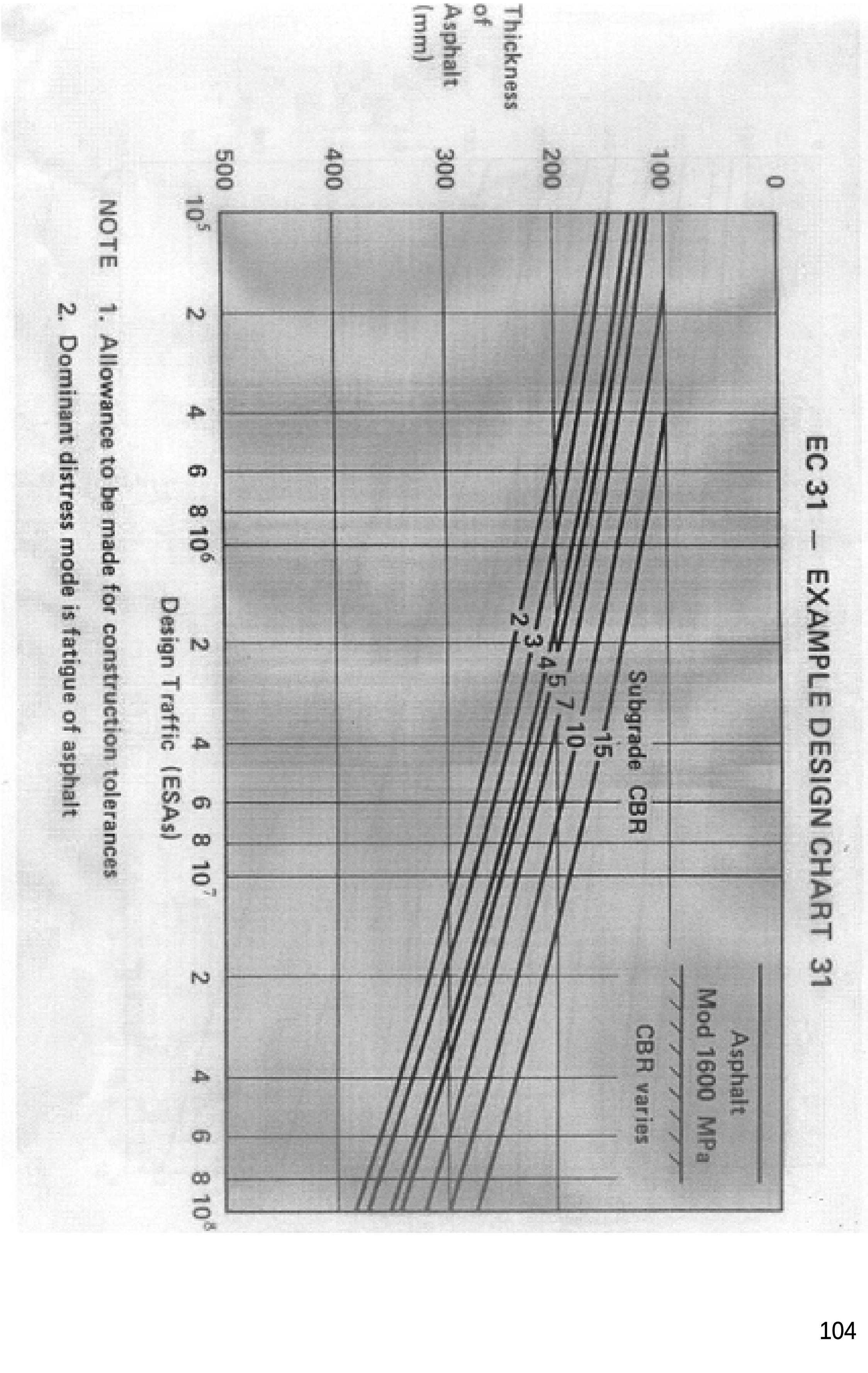
K:\RDB\MAT LAB\Mat Lab\Reports\Investig

K:\RDB\MAT LAB\Mat Lab\Reports\Investig

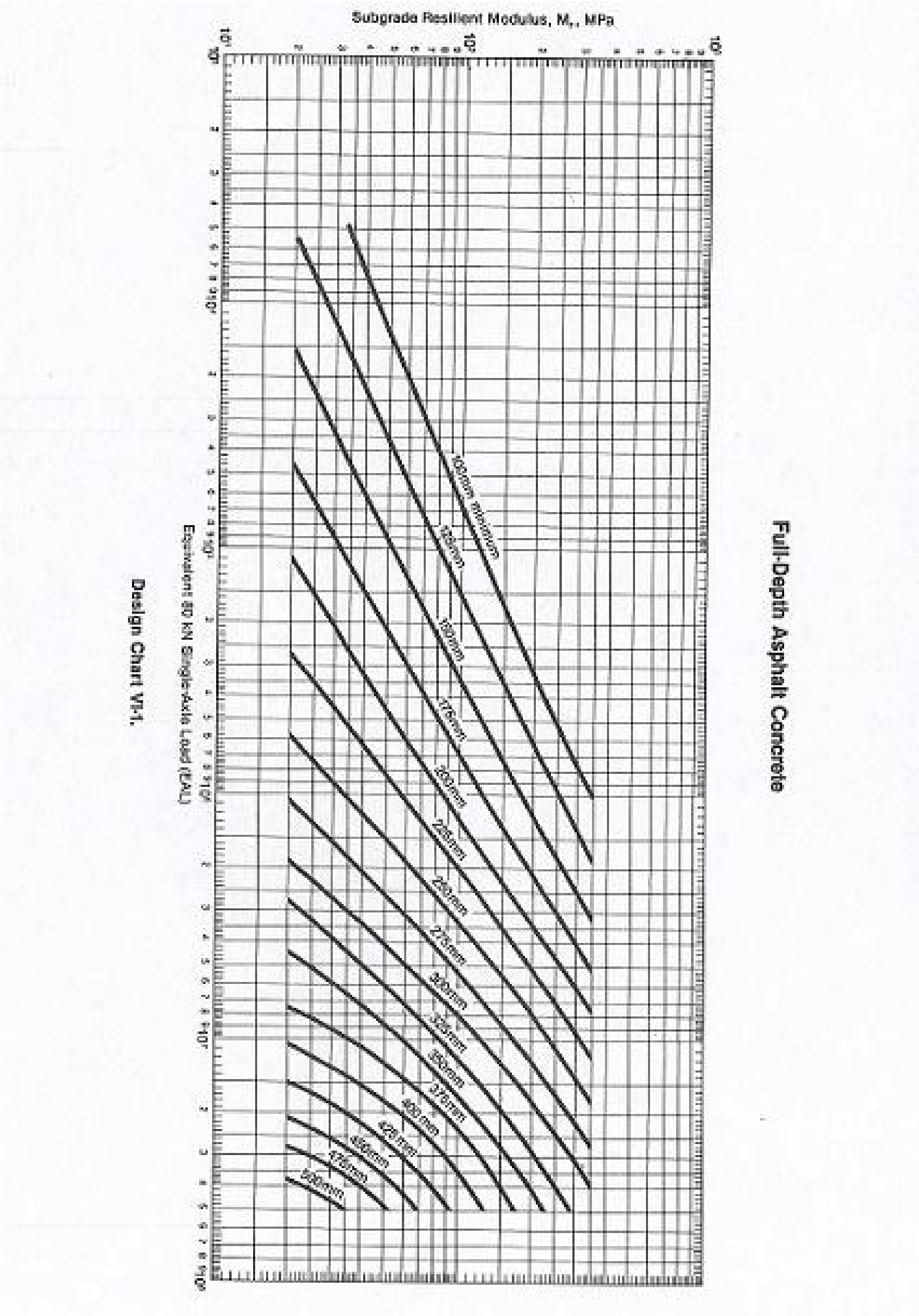
P:\Pine Street CBR reports.pdf

P:\Pine Street, Flinders View - Site Pl

Appendix F – Design chart example for Foam Bitumen Pavements



Appendix G - Full Depth asphalt design charts



Appendix H - ICC business case for the trial of geogrid technology.

F. JJC:JJC
H:PSB\Construction\Projects\Cm Numbers\7000 to 8000\ECM07514 Cedar Rd\Bus Case for Tensar.doc

4th September 2009

MEMORANDUM

TO: PROJECT SERVICES MANAGER

FROM: PRINCIPAL ENGINEER - CONSTRUCTION

RE: CASE FOR TRIALLING NEW TECHNOLOGY -GEOGRIDS

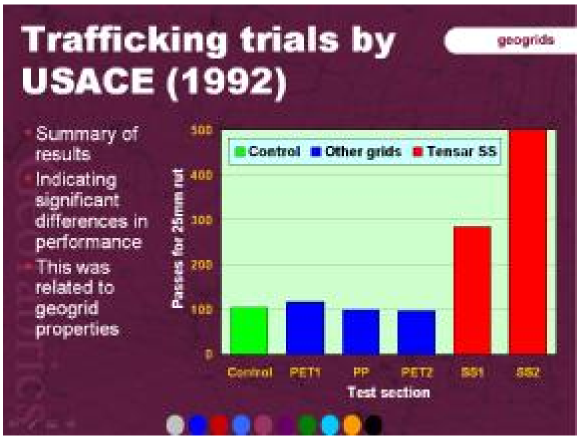
Background

In the interest of keeping Ipswich City Council at the cutting edge of pavement technology, investigations have been underway to determine if better methods can be found to replace the full depth granular pavements that are commonly used for our road construction. One such product found is the TX160 Geogrid sold by Geofabrics Australia.

Recommendations for use of the product came initially from Mr Raad Jarjees, Senior Manager, Infrastructure Delivery (North) at Moreton Bay Regional Council. MBRC have successfully used the product in various situations including Stanley St, Strathpine. The original design specified 590mm of gravel pavement over the CBR 2.5% clay subgrade. A Tensar solution was adopted with 300mm type 2.3 CTB over the Tensar grid, and to date, 3 years on, the pavement shows no signs of distress.

A case study with a longer history in Australia is Samphire Drive in Townsville, the only access road for 10 Terminal Regiment, the Army's amphibious vehicle regiment and the Ross Island Facility. The road was constructed in 1992 across swamp lands using the Tensar technology and was tested in 2007 for roughness count and the pavement was still superior to the benchmark for new road construction.

History of the product dates back to 1992 with the United States Engineers Corp, who performed trafficking trials and proved the superior performance of this product. A full analysis of the product is included in the attached PowerPoint demonstration courtesy of Geofabrics Australia.



CBR = 3% AASHTO	actual thickness	factor	effective thickness	standard axles
Control	400	1.00	400	9,000
SS20	400	1.25	500	35,000
SS30	400	1.38	552	64,000
TX160 perm	400	1.44	576	113,000
TX160 temp	400	1.5	600	146,000

Charts and graphs courtesy of Geofabrics Australia

Proposal

Cedar Road, Redbank Plains, is a local collector with existing pavement showing severe signs of distress to the point that project ECM07514 has been issued to install drainage, K&C and rehabilitation of pavement from Ch150 to Ch282. The CBR of insitu blacksoil subgrade is 2.0

Issued project design consists of the following pavement layers:

- 40mm Dg14 AC wearing layer
- 125mm type 2.1 gravel
- 125mm type 2.3 gravel

- 125mm type 2.4 gravel
- 300mm Subgrade replacement layer, min CBR 15

According to the AASHTO method, this full depth gravel pavement design has a life of 2*10^6 ESA's with a reliability level of 55%. Issued estimate for this project is $457,989.

Utilising Tensar technology with the same ESA and reliability parameters from the original design, new pavement design can be:

- 40mm Dg14 AC wearing layer
- 125mm type 2.1 gravel
- 150mm type 2.3 gravel
- 150mm type 2.4 gravel
- Layer of TX160 Geogrid.

Verification of the original pavement strength is shown in the attached document.

Cost/Benefits

The original estimate has been revised in line with the proposed pavement change, taking into account the reduction in excavation and subgrade replacement layer, then adding on the cost of the Tensar and extra thickness of upper and lower sub base.

The revised estimate shows a primary saving of $51,021 (modified lines shown in bold red), or approximately 11% of the original estimate. Secondary savings could also be realised but remain uncosted:

- The reduction in excavation depth could remove the requirement for service relocations , Telstra/Gas/Water etc. (Not applicable in Cedar Rd)
- Time savings from excavation and pavement reduction lessens the risk of the blacksoil subgrade being exposed to a rain event. As the box is excavated to depth linearly, the subgrade is exposed for long periods of time. If an adverse weather event occurred (such as on Spengler St), significant time is lost in waiting for the subgrade to dry out, and saving effort in trying to get residents into their homes.

- A definite time saving would be realised with a shallower excavation in spending less time daily installing and removing temporary driveways each morning and night giving residents access to their properties and reducing the ramp length in driving traffic through the box.
- Further indirect / overhead savings would be realised by the reduced timeframe like Traffic Control, project managers time, administration overheads, site supervision etc.
- Also to be considered is the cost to the community and residents. How do you put a price on the peace and quiet that the residents will enjoy by having the project finish a week or two earlier?

Issues for Consideration

While the Geogrid itself is a polymer and will last indefinitely, consideration needs to be given when the road may need to be opened in the future for new services to be buried. The supplier assures that the product will break when struck by an excavator and not pull large sections of the road up. In this case the trench will need to be over excavated by 100mm either side and a replacement layer can be tied to the existing grid to retain the structural integrity. Council will need to put conditions on the restoration of the pavement, and Councils DBYD response should be used as a vehicle to promote the fact that the grid exists under the pavement.

Recommendation

That Tensar Geogrid TX160 be trialled as a replacement gravel layer at the Cedar Rd rehabilitation project, with expected savings of $50 000.

Jeff Crone
Principal Engineer - Construction

I Concur	I Concur
Maurie McGuire	Ross Drabble
Project Services Manger	Engineering Services Manager