EMULSIFIED BITUMINOUS MATERIALS IN ROAD MAINTENANCE & CONSTRUCTION

A SURVEY OF CURRENT NEW ZEALAND PRACTICE

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AN IMPORTANT NOTE FOR THE READER

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I have drawn also on past experience in the supply of emulsion to the Taranaki Roading and Civil Engineering Companies and wish to express my appreciation to John Clentworth, TRACE Companies (New Plymouth), for input regarding historic contracting concerns.

The referenced contacts are by no means the only sources of experience and expertise in emulsion manufacture and usage. I was made aware of other city councils who are proactively and successfully using emulsions. It is my belief that the information summarised is representative of the national experience in emulsion usage.

I wish also to thank John Donbavand for his constructive criticism in preparation of this report.

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EXECUTIVE SUMMARY

Advances in materials and applications technology and incorporation of new technology into industry is a dynamic process in which many variables play a part.

Bitumen in an emulsified form has been used in almost every application in which hot, cut-back or fluxed bitumen binders are used. The use of bitumen emulsions in the road construction and maintenance industry is an example of emerging technology that is offering improvements in safety and environmental impact as well as performance. Effective performance and safer handling can be demonstrated in both past and current use of emulsified bituminous materials in New Zealand. No measure of the positive environmental impact of increased use of bitumen emulsions or, conversely, the decreased use of cut-back bitumen, has been undertaken so far in New Zealand.

The negative environmental effects of using volatile cutter stocks as temporary viscosity reducers and wetting agents are: 1. the release of volatile hydrocarbons into the atmosphere, contributing to pollution, and 2. the unnecessary use of a non-renewable resource.

Performance-related improvements through use of bitumen emulsions include: 1. greater control over residual binder application rates, 2. thinner bitumen films where required, and 3. reduced bitumen oxidation which may correlate to greater resistance to cracking and ravelling in mixes and longer chip retention and resistance to cracking in seals.

The use of bitumen emulsions in other countries has been influenced by factors such as energy costs and environmental impacts. While documentation of the influence of these factors on technology development and the economic impact of changing technologies on total road construction and maintenance costs in other countries may be of value in providing a model for a similar assessment appropriate to New Zealand's roading network, it is not within the scope of this research brief.

As a starting point for evaluating the factors which limit bitumen emulsion use in New Zealand and as a basis for establishing research needs, a survey of practices from 1987 to 1991 is presented here, along with an indication of current trends. The period 1987 to 1991 was chosen because it is a period for which Transit New Zealand records are most readily available. Records used correspond to financial years.

ABSTRACT

Bitumen emulsions are now being used in almost every application in which hot, cut-back or fluxed bitumen binders are used. A survey of current practice in New Zealand for road maintenance and construction from 1987 to 1991 is recorded. Experience ranges from using bitumen emulsion for maintenance, tack coat, sealing, and slurry applications for State Highways, City streets and Council roads, and in Transit New Zealand regions.

Binder performance of bitumen in general is discussed, with particular reference to the effects of heat, oxidation, cutter and fluxing stocks, and emulsification. Acceptance criteria for bitumen emulsions are specified in terms of stability, curing characteristics, and resistance to stripping.

The summary provides volumes of bitumen used annually in New Zealand, applications used for bituminous emulsions, comparison of costs of hot bitumen with those of bitumen emulsions, as well as lists of benefits and limitations of bitumen emulsions.

Recommendations for future action include development of a Bitumen Emulsion Sealing Manual in which guidelines for application procedures are established, evaluation of the sand circle method for establishing emulsion application rates, and development of a test procedure for assessing potential moisture damage. Also included are ways to address the limitations of emulsions and to increase emulsion use in New Zealand.

1. SUMMARY OF APPLICATIONS FOR BITUMEN EMULSIONS

Bitumen in an emulsified form has been used in virtually every application in which hot, cut or fluxed bitumen binders and sealants are used, with differing degrees of effectiveness, differing handling and application requirements, differing cost structures and, in some applications, differing performance levels.

A summary of applications for bitumen emulsions for which guideline specifications are published by the US Asphalt Emulsion Manufacturers Association (1981) is shown in Appendix 1.

This compilation of bitumen emulsion applications encompasses the experience of the New Zealand roading industry. Although no one supplier manufactures bitumen emulsions for every application and no one contractor or region has experience with each of these applications, every application, with the exception of construction and cold recycling mixes, has been used in at least one Transit New Zealand Region by a regional or local body.

2. SURVEY OF CURRENT NEW ZEALAND PRACTICE FOR ROAD MAINTENANCE & CONSTRUCTION

2.1 Introduction

New Zealand currently employs road maintenance and construction practices that use both hot bitumen binders with and without hydrocarbon solvent "cutters" for temporary viscosity reduction, and bitumen binders in water-based emulsified form. In some applications one form of binder is used exclusively, while in other applications the use of emulsified or hot or cut-back bitumen has been interchangeable.

2.2 State Highway Use

Applications using bitumen emulsions (abbreviated hereafter as "emulsions") on New Zealand State Highways from 1987 to 1991 ([1]) are listed in Appendix 2 by Transit New Zealand region. Appendices 2.1, 2.2 and 2.3 summarise total square metres used in each region for each application.

From interviews with Transit New Zealand regional management regarding specific aspects of various applications, the following information was provided.

2.2.1 Maintenance Applications

Maintenance applications, including void filling, texturising, lock coating, pothole filling and patching with emulsions, are currently or have at some time been carried out in areas of all Transit New Zealand regions. Emulsions are used exclusively for these maintenance applications in some regions, while in others emulsions are used only seasonally.

In regions where emulsions are used exclusively, the reasons for preferring emulsions include:

- better tolerance to marginal weather,
- better control over application rates,
- fewer production delays because heating of binder, to the same extent as cut-back binder, is unnecessary,
- ability to transfer and store maintenance emulsion mixes for effective patching and repair in remote locations,
- safer handling,
- environmentally acceptable.

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(1) Applications by year correspond to financial years as follows:
87/88 - 1 April 1987 through 31 March 1988
88/89 - 1 April 1988 through 31 March 1989
89/90 - 1 April 1989 through 30 June 1990
90/91 - 1 July 1990 through 30 June 1991

In regions where emulsions are used only in the off-season but cut-back bitumen is used for similar applications in-season, preference for using cut-back bitumen was not based on performance criteria. Reversion to use of hot binders was generally contractor-influenced to facilitate effective use of contractor equipment.

Where problems have been encountered using emulsions for maintenance applications, factors cited include:
- being used in unacceptably poor weather conditions,
- inexperience in handling leading to frothing and plugged spray tips.

2.2.2 Tack Coat Applications

Although emulsion used for tack coating does not appear as a category of emulsion use in the RAMM (Road Assessment and Maintenance Management) database, emulsions are used almost exclusively for this purpose throughout New Zealand. Tack coats are routinely used under hot-mix friction course, emulsion mixes, patching compounds and some slurry treatments. Emulsions used for tack coating include anionic and cationic quick-breaking formulations with 55 to 68% residual bitumen of both 180/200 and 80/100 penetrations. No problems with use of emulsion tack coats were cited.

2.2.3 Sealing Applications

Single-coat and two-coat seals are used extensively in several Transit New Zealand regions and service life is deemed to be equivalent to any standard bitumen seal with or without cutter stock.

Although, according to Appendix 2, some regions appear to use no emulsions, discussions with Transit New Zealand regional managers confirm that emulsions are commonly used for maintenance applications in some areas under their jurisdiction. The RAMM database depends on the amount of information recorded at the time that the work was done. For historical data, there were omissions that may have led to inaccuracies.

The use of two-coat emulsion seals is increasing. These emulsion seals are considered to be demonstrably cost-effective, both compared to single-coat seals with decreased life expectancy (Houghton 1987) and in comparison to use of hot bitumen binders (RRU 1988). Three-coat seals have been trialed along with Grade 3 seals and have been felt to be both cost and performance acceptable.

Preferences cited for using emulsion seals, with or without cutter stock, include:
- less sensitivity to application rate variation,
- reduced tendency to flush,
- better tolerance to marginal weather conditions, and therefore extension of productive sealing season,
- no excessive delays associated with binder heating,
- safer handling,
- environmentally acceptable.

Problems cited in association with emulsion seal coats include:
- attempts to seal in unreasonably severe weather conditions, which were based on the assumption that constructing emulsion seals is possible in the most extreme conditions of low temperature and imminent rainfall,
- difficulty in establishing optimum binder application rates using conventional sand circle methods,
- perceived pollution from run-off of brown water caused by rain falling immediately after sealing. (However, lack of chip loss indicated that emulsion had coalesced (broken) sufficiently to hold chip and no damage to seal had resulted. Brown water most likely consists of neutralised salts of emulsifiers.)

One instance of serious ravelling in a two-coat seal was reported. Ravelling was originally attributed to marginal weather conditions, but another instance of top-coat ravelling where sealing was done under optimum conditions may indicate difficulty with establishing optimum application rates, or a tendency to stripping with a specific aggregate(2). Bleeding has occurred over smooth patches where uniform two-coat emulsion seals have been placed over non-uniform surfaces. This is contradictory to claims that emulsions resist this type of bleeding, which is expected in standard sealing.

2.2.4 Bitumen Emulsion Mix Applications

The use of emulsion mixes has been limited to maintenance and corrective applications. Use of emulsion mixes for original construction or reconstruction was not reported.

Emulsion mixes, which include open-graded emulsion mixes (OGEM) and friction course (FC), were described as very appropriate for corrective work for the following reasons:
- reduced tendency for bleeding,
- good overlays for flushed areas,
- practicality of handling, transporting and storing mixes without need for large manufacturing plants close to site,
- slight elastic nature of open-graded mixes is appropriate for use over minimally cracked pavements,
- economic,
- good storage stability,
- versatility because of improved workability, that is not possible with hot bitumen mixes.

Difficulties associated with using emulsion mixes pertained to those associated with open-graded mixes, and included:
- difficulties of establishing optimum binder application rate on an open-textured surface,
- tendency to ravelling,
- lack of durability encountered with open-graded mixes.

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(2) Because cationic emulsions are manufactured with chemicals that have bonding properties similar to adhesion agents, adequate adhesion is assumed. No modification of the Vialit procedure to accommodate testing of emulsion seals for stripping resistance has yet been undertaken.

These kinds of failure should be evaluated to determine if moisture-associated stripping is occurring or if binder film thicknesses are insufficient.

2.2.5 Slurry Applications

Slurry mixes were reported to be acceptable in performance as seals and for shape correction (wheel rut filling and overlays), with the following advantages:

- control of finish texture, permitting use over flushed areas as well as providing good dense seals like those of chipseals,
- elimination of the loose chip associated with conventional seals,
- effective levelling and skid-resistant surfacing in the one layer.

2.3 City Street and Council Road Use

Use by City Councils ranged from no use of emulsions to virtually exclusive use of emulsions. Their general comments were similar to the comments of users of emulsions on State Highways.

Councils of cities in which emulsion manufacturers are located were generally more knowledgeable about use of emulsions and generally pro-active in using emulsions in preference to hot bitumen seals.

City Council engineers cited a preference for emulsion technologies as they were cleaner and more efficient, especially for the use of emulsions as slurry seals and for elimination of loose chip. Heavy traffic volumes on urban streets and difficulties in re-routing traffic were cited as reasons for requiring extremely fast setting times. However run-off from emulsions must be reduced if their use is to predominate in urban areas.

Amalgamation was most often cited as the reason both for loss of the information that is based on past experience and for uncertainty of future practice. Some problems associated with inexperience were cited as being responsible for less use of emulsions in some areas. A desire to remain or become pro-active in the use of emulsions was expressed by several city council engineers, but it was qualified by the reality that consulting engineers have limited knowledge in the use and specification of emulsions and are therefore inclined to consider only uses having existing, well recognised, and published specifications.

City Council use of emulsions for sealing ranged from 100% by Dunedin City Council prior to 1991([3]), to just over 50% for Christchurch City Council, to less than 5% (but increasing) use by Auckland City Council.

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(3) A reduction from nearly 100% emulsion use for sealing to less than 50% emulsion use occurred in 1991 when Dunedin City Council lost expertise for supervision of emulsion sealing projects.

CQ (cationic quick setting) emulsion, at 60 to 70% (residual bitumen), or CRS-1 (cationic rapid setting ≥55% bitumen) or CRS-2 (cationic rapid setting ≥63%) emulsions, were most often specified for sealing applications by City Councils.

2.4 Transit New Zealand Regional Use

Grades of emulsion currently specified by Transit New Zealand regions for the applications cited in Appendix 1 are listed in Appendix 3. In general, cationic emulsions are used for all applications. Some anionic emulsions are still used for tack coat and some maintenance applications. Emulsion designation however is the data entry variable that most often has not been entered in the RAMM database.

Cationic emulsions are often generically specified as cationic quick breaking, those with residues above 60% being accepted for maintenance applications, and those with residues above 65% being accepted for sealing applications. For example, emulsions specified for sealing applications tend to be CRS-2, CQ67, CQ68 or CQ70 (i.e. 67%, 68%, 70% bitumen respectively). Emulsions specified for maintenance mixes include CRS-1, as well as CQ designations.

Emulsions available for tack coating cover a wide range, from slow to quick breaking, anionic to cationic, with 50 to 60% residues, and specified by both City Councils and Transit New Zealand regional sources.

Generic emulsions are available which also generally meet Transit New Zealand criteria. The ability of an emulsion to perform appears to be accepted, with relative unconcern for specification criteria.

Emulsion specifications reflect quality, and acceptability of emulsion quality was unquestioned, even though the relationship between specifications and setting characteristics is poorly understood. Except for some trials, conducted several years ago in Auckland and Hamilton, which were not successful, emulsion quality was never cited as a problem. Emulsions have also improved since then.

3. EMULSIFICATION & PERFORMANCE PROPERTIES OF BITUMEN

3.1 Effect of Heat

The usefulness of bitumen to bind aggregate in any stabilising, load-bearing, aggregate-binding or waterproofing treatment lies in the rheological and chemical properties characteristic of the bitumen. These properties include, among others, sufficient viscosity or resistance to flow at service temperatures to bind aggregate in place, sufficient ductility to resist brittle fracture under load, and a degree of affinity for an aggregate surface. Because of its thermoplastic nature, bitumen is easily liquefied by heating and readily returns to its more viscous, serviceable state on cooling.

In general, the grade of bitumen selected for a particular application is largely determined by the service temperature properties of that bitumen.

3.2 Effect of Oxidation

In the presence of oxygen, bitumen undergoes oxidative aging. This process changes the initial properties of bitumen and is accelerated with temperature increases.

This aging is most pronounced during exposure of thin films of bitumen, and of bitumen in drum (turbulent-mass) plants. It is the basis for the AR (aged residue) bitumen grading system, which was established to better define the properties of the bitumen after its exposure to oxidative aging during manufacture of asphaltic concretes.

Oxidative aging results in a loss of ductility and in an increase in resistance to plastic flow, which are indicated by increased viscosity, decreased penetration and an increase in the glass transition temperature, all of which eventually lead to brittle failure in the bitumen.

In all applications, bitumen undergoes oxidative aging in service. The rate of aging is dependent on the composition of the bitumen, the concentration of available oxygen, and temperature. Specifications formulated by Transit New Zealand define the susceptibility or resistance of a bitumen to aging by specifying a minimum number of days before exposure to an oxidative aging regime causes excessive brittleness. Trials in progress (Works & Development 1991) and supplementary test data obtained as part of RRU Project AB/6 (RRU 1988) indicate that oxidative aging progresses at a slower rate than that predicted by Australian correlation studies. This is almost certainly a reflection of the incomplete understanding of the aging mechanism of bitumen and the relevance of environmental factors and bitumen composition to the mechanism.

The benefits attributed to improved durability of emulsions over hot bitumen are not significant for sprayed seals because, in general, the relatively low amount of heating required for storage, transport and application of hot bitumen for sealing purposes does not significantly alter its properties. However, because the manufacture of emulsions is at low temperatures compared to the manufacture of hot bituminous mixes which requires exposure of large surface areas of bitumen at elevated temperatures, an emulsified binder would be expected to exhibit some degree of improved durability.

In bitumen/aggregate combinations where the degree of affinity between the bitumen and the aggregate surface is insufficient to ensure adequate resistance to moisture damage resulting in adhesive failure, antistripping or adhesion agents are incorporated in the bitumen.

Temperature plays a role in the efficacy of these antistripping agents as it affects their abilities to function as adhesion agents because of heat degradation and also because of their relative molecular mobility within the viscous bitumen.

In general, if durability of a bitumen is defined as "the resistance to change in original properties during construction and service", the acceleration of oxidative and decomposition reactions by heating in the presence of atmospheric oxygen should be avoided whenever possible. Therefore, liquification of bitumen by emulsification minimises oxidative aging because of the reduced heating requirements, and it potentially eliminates the need for adhesion agents which are readily heat degraded.

3.3 Effects of Cutter and Fluxing Stocks

The effects of cutter and fluxing stocks on bitumen should be considered in terms of its function and rheology, rather than its chemical properties.

The function of cutter stocks added to bitumen is to:
- temporarily reduce the viscosity,
- facilitate good wetting of aggregate,
- extend mixing times or workability of mixes,
- penetrate dusty surfaces, and
- prime the surface for bonding with subsequent seals.

Cutter and fluxing stocks typically used in New Zealand include kerosene and automotive gas oil (AGO, commonly called diesel fuel). Kerosene is used for cutting or short-term viscosity reduction, and AGO is used to achieve more permanent, longer term softening, or fluxing. Neither of these stocks appears to have significant effects on the chemical properties of bitumen. Removal of most of the cutter by low temperature distillation results in restoration of near-original bitumen properties.

The rheological properties of bitumen are, however, affected in service by time. Variation in rheological properties over extended periods of time is a function of exposure to temperature and humidity, cutter stock volatility and composition, and film thickness of cut-back binders.

Cutter or fluxing (diluent) residues left in bitumen maintain viscosities at levels lower than those which would be predicted, unless they have been considered as part of the design. In fact, combined oxidative aging and loss of diluent take place simultaneously in cut-back and fluxed bitumens during the service life of seals. Both these variables are also dependent on climatic conditions and so pose problems in accurately predicting binder properties at any point in time.

Problems associated with low viscosity binders, such as chip loss through rollover, or bleeding and flushing, have been known to occur in summer months with cut-back bitumens that have been applied after the sealing season when, because of the lower temperatures, larger quantities of cutter have had to be added to the binder.

3.4 Effect of Emulsification

Although emulsification of bitumen with cationic emulsifiers alters the surface chemistry of bitumen and contributes positively to adhesion at the bitumen/aggregate interface, limited analysis of recovered residual bitumen used in New Zealand sealing trials in the mid-1970s showed no significant differences in long-term aging between emulsified bitumen and cut-back bitumen. In specification compliance testing, residual bitumen recovered by vacuum distillation from emulsions, both anionic and cationic, shows no significant variation from original properties.

Although emulsions may be modified to contribute significantly to improvement in performance characteristics of the bitumen, commercial emulsifiers that are commonly used would not be expected to alter performance characteristics measurably, with the possible exception of an improvement in adhesion.

4. ACCEPTANCE CRITERIA FOR BITUMEN EMULSIONS

4.1 Introduction

Emulsion acceptability is generally specified in terms of its stability during the storage and handling period required by the application, and in terms of its mixing and curing characteristics. Resistance to stripping caused by moisture damage is essential for any emulsion whether used as the binder in a chip seal or as a mix.

4.2 Stability

Stability in storage was not cited as a problem by the staff interviewed in this survey. Drum and bulk storage of emulsions was indicated as being acceptable for 3 to 6 months. This period was considered to be adequate as an acceptance criterion of stability.

Most emulsions however are not stored by the user and emulsion suppliers are generally aware of a users' storage and handling needs before they supply the emulsion. The storage needs that are required by users are being adequately met by the stability of the emulsions that are available.

4.3 Curing

The acceptability of binders used in sealing operations is most often measured in terms of their ability to quickly bind and retain chip, to maximise construction productivity, and to minimise traffic delays. Curing characteristics and emulsion viscosity are interrelated.

Problem areas in curing and breaking characteristics include run-off associated with low viscosity, and chip loss or rollover associated with delayed breaking. In general, a thinner emulsion layer will break faster because of increased surface area evaporation. The requirement of increased viscosity to reduce binder run-off, and to ensure more rapid curing and binder strength development, may be achieved by increasing the residual bitumen content. This also decreases the amount of water in the binder and the associated transportation costs.

Acceptability of binders used for mixing with aggregates is measured in terms of their ability to coat aggregate and to withstand the shearing forces associated with mixing, without breaking and causing fines to "ball up".

High residual emulsions, containing more than 75% residual bituminous binder, are not currently available in New Zealand. They have been manufactured but not on a commercial scale, and they have not been subject to field trials. Refining the use of these high residue emulsions will require the co-operative efforts of funding agencies, contractors and emulsion formulators, with each having the wish to perfect the system through trial and error methods for different uses.

4.4 Stripping

Although moisture-induced stripping has not been reported, an increased use of larger aggregate, single-coat seals (that will entrap more moisture and slow evaporation) will test the bitumen/aggregate bond to a greater degree than do fine aggregate and multiple-coat seals being used currently. Consideration may have to be given to development of a Vialit-type adhesion adequacy test as an acceptance criterion.

Stripping of chip in emulsions was noted in one instance but this was thought to be caused by incomplete emulsion break, and not to moisture damage. Some ravelling that has been reported has been attributed to insufficient binder, when application rates as determined by the sand circle method were used.

5. SUMMARY

5.1 Volumes of Bitumen Used in New Zealand ([4])

The total volume of bitumen used by the New Zealand roading industry is between 100,000 and 125,000 tonnes annually. Of this volume, an estimated 6 to 8% is used in an emulsified form, 10 to 15% is used as binder in hot mix, and the remainder as spray-applied binder in chipseals and maintenance applications.

Use of diluents vary considerably from use in all seals (in lower South Island) to seldom, if ever, used in seals (in upper North Island). The areas with the greatest need for use of cutter stocks are also the areas of greatest emulsion use.

5.2 Applications of Bitumen Emulsions in New Zealand

With the exception of emulsion for recycled mix binders and emulsions for construction mixes, every emulsion application cited in Appendix 1 has been successful in New Zealand.

Where emulsion applications have been successful in the past, no reluctance was expressed by works superintendents or agency engineers to continue such applications. The fact that emulsions are not a panacea for all sealing applications and that they must be incorporated responsibly into project specifications is appreciated and prevalent among all interviewees, a reaction that is based on past failures.

The attitude toward use of emulsions was in general extremely positive except for two interviewees whose concern was loss of freedom of choice of materials. However, interest in resolving problems encountered on emulsion jobs was lacking, and preference was to revert to use of familiar materials.

Lack of information and knowledge of not only what emulsions to specify but how to handle and use them were cited as reasons that greater use of emulsions is not made.

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(4) Emulsion use percentages are based on confidential sales volumes supplied by manufacturers. Where volumes were not supplied, volumes were assumed to be similar to known volumes in other geographic areas, and adjusted from information on emulsion use from both City Council and Transit New Zealand regional sources. Bitumen volumes used in hot mixes were similarly derived using the RAMM database as a starting point.

5.3 Hot Bitumen and Bitumen Emulsion Costs

When comparing the use of hot bitumen with emulsion, costs should be based on the following considerations:

Hot Bitumen
- Binder material costs, in litres per square metre,
- Heating costs for required temperature maintenance,
- Labour costs for addition of diluent,
- Diluent costs,
- Labour costs for addition of adhesion agent,
- Adhesion agent costs,
- Plant costs during diluent mixing,
- Plant costs during adhesion agent mixing,
- Transport costs per litre of bitumen,
- Long-term maintenance costs associated with hot and cut-back bitumen seals.

Bitumen Emulsions
- Binder material costs, in litres per square metre,
- Heating costs for required temperature maintenance,
- Transport costs per litre of bitumen,
- Long-term maintenance costs associated with emulsion seals.

Heating costs are dependent on many variables which include equipment insulation, bitumen loading temperature, ambient temperatures and transport distances. Similarly, the need for diluents depends on ambient conditions at the time of sealing. Because of these ambient factors, a direct comparison of initial costs between hot bitumen and emulsion seals cannot be applied to every project.

An accurate evaluation of the true cost differentials between the use of emulsions and hot binders in sealing should be based on both construction and long-term maintenance costs of equivalent applications.

5.4 Benefits of Bitumen Emulsions

Many factors make the use of water-based emulsions preferable to use of cut-back bitumens. These factors include:
- reduction in the use of environmentally undesirable (air polluting) hydrocarbon solvents,
- increased energy efficiency associated with less use of a non-renewable resource,
- increased employee safety with less handling of
  - molten bitumen,
  - flammable materials,
- improved employee health, as inhalation of volatile hydrocarbon fumes is lessened,
- reduction in costs associated with degradation of adhesion agents,
- reduction in maintenance costs associated with flushing related to variations in application rates (related to temperature/viscosity),

- reduction in maintenance costs associated with cutter stock softening of bitumen.

It should be realised that small amounts of cutter are often added to emulsions used in mixing applications.

5.5 Limitations of Bitumen Emulsions

Specific factors which appear to be limiting emulsion use in sealing and mixes include:

- too frequent run-off associated with low viscosity,
- too slow setting, in some instances,
- higher costs of the material,
- lack of knowledge in the use and handling of emulsions.

6. RECOMMENDATIONS

6.1 Emulsion Sealing Manual

The greatest need appears to be the establishment of guidelines for application procedures, modelled on the range of applications which have proven to be effective, with a view to the development of a Bitumen Emulsion Sealing Manual, similar to the Bituminous Sealing Manual published by Transit New Zealand in 1991.

6.2 Sand Circle Method Analysis

Another need is to design a trial to evaluate further the applicability of the sand circle method of establishing rates for applying emulsions. This evaluation could be achieved by trialing application rates to cover the entire range from bleeding to chip loss failure and would also establish an optimum range of application rates. A comparison of this range to pre-determined sand circle predictions would result in either correlation with the existing test method or confirmation of its adequacy. This trial would need to be carried out for a range of emulsion viscosities and surface textures.

6.3 Test Procedure for Potential Moisture Damage

Development of a test procedure, similar to the Vialit test, should be considered to assess the potential for stripping where an emulsion is to be used in a coarse aggregate single-coat seal.

6.4 Overcoming Limitations of Bitumen Emulsion Use

Several potential ways can be used to address the cited limitations. Products in other countries have been developed to address specific needs as follows:

- **Reduction of run-off** by developing
    - high residual bitumen emulsions,
    - high float emulsions,
    - polymer-modified emulsions.

- **Improved curing times** by developing
    - rapid curing emulsions,
    - microasphalts (rapid setting mix systems).

State-of-the-art technology includes development of formulations, equipment and application processes to improve efficiencies in the use of emulsions.

- **Cost reduction** by
    - increasing the volume of production of emulsions,
    - co-operative development programme for emulsions and their uses.

- **Information dissemination** by
  - industry forums directed toward innovative practices,
  - practical workshops on specific applications,
  - design of cost-benefit models to establish cost-benefit profile over time.

6.5 Increasing Bitumen Emulsion Use

Increased emulsion use has obvious benefits for road maintenance and construction in New Zealand. Strategies and policies which have been effective in facilitating and encouraging transition to more advanced technologies for road maintenance and construction in terms of occupational health and safety, environmental protection, efficiency and long-term cost benefits, and which are recommended, include:

- innovation/demonstration projects,
- funding allocated specifically to technologies that reflect improvements in safety, environmental impact, efficiency or cost benefit,
- quality-planning groups to develop and audit strategies.
- expansion of RAMM database fields to include construction cost and ambient conditions to confirm long-term cost-benefits.

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APPENDIX 1 SUMMARY OF APPLICATIONS FOR BITUMEN EMULSIONS

Application	Effectiveness
1. Tack Coat	Emulsions are an extremely effective way to apply the low application rates of bitumen required for tacking a surface before patching or overlaying.
2. Prime Coat	Prime coating is intended to bind or consolidate the upper 10 - 30mm of a basecourse or natural soil without mechanical mixing. Highly cut bitumen (1:1 bitumen-kerosene) is effective in "carrying" bitumen into soils for penetration in these applications. Solvent-free, very dilute, water-based emulsions have less ability to penetrate soils to sufficient depths to be effective. Environmental concerns over entry of hydrocarbon diluents into ground waters have made this traditional solvent (kerosene)-based application almost obsolete, in favour of various methods of in-situ mixing of emulsified bitumen with soils or basecourses to achieve coating and consolidation (see also 8.1 Soil Stabilisation, Dust Palliatives).
3. Dust Palliative	Very dilute emulsions are effective as binding agents to control surface dust on building construction sites and low traffic-volume unsealed roads. Although simply watering such areas for dust control is effective, the use of bitumen emulsions extends the dust control period and reduces the frequency of application. Emulsions are preferred for use as dust control agents to environmentally unacceptable recycled oils which have the potential to pollute ground waters.
4. Fog Coats	The application of a light "fog" of emulsion, generally diluted to 15-25 pph bitumen, can ensure against chip loss where a seal may not have enough binder to retain chip. Emulsions can also rejuvenate and prolong the life of oxidising, but intact, asphaltic concrete. These are cost-effective preventive maintenance treatments which use quick setting emulsions.

5. Maintenance Mixes		Controlled break, cationic, medium- or slow-setting mixing-grade emulsions are employed in maintenance mixes.
5.1	Central Plant Mixed, Not Stockpiled, Blade Laid 5.1.1 Open-graded 5.1.2 Dense-graded	These mixes generally contain small amounts of solvent and eliminate the need for the heated mixing plant and hot storage tanks that are associated with hot mixes. These mixes are suitable for patching. Where mix stability under ambient conditions is adequate, mixes may be used for shape correction and overlay.
5.2	Site Mixed, Machine Laid 5.2.1 Open-graded 5.2.2 Dense-graded	Site mixing and machine laying can significantly reduce or eliminate the need for solvents in mixes. Mechanical mixing and placement of emulsion mixes is efficiently done on site with different types of travel plant and mixing equipment. The emulsion type used is determined by the efficiency of mixing equipment. Low-shear mechanical mixing will require slower setting emulsions with longer mixing times. High-shear mixing equipment can utilise fast-setting emulsions, which result in greater production volumes and reduced production time. Generally, medium-setting emulsions are used for open-graded mixes; slow-setting emulsions are used for dense-graded mixes (Note 1).

NOTE 1: The terms "medium-setting" and "slow-setting" pertain to the ability of the emulsion to mix and coat aggregate without breaking and should not be confused with traffic times. Slow-setting "mixing grade" emulsions should give enough "working time", once a dense-graded mix has been uniformly coated with emulsion, to allow effective placement and compaction. A medium-setting "mixing grade" emulsion should give an equivalent working time in an open-graded mix. Both mixes should be ready for compaction and traffic within several minutes of laying.

5.3 Stockpile Mixes

5.3.1 Open-graded

5.3.2 Dense-graded

Although stockpile mixes are manufactured with emulsified bitumen, these emulsions generally contain high levels of cutter stocks. The use of emulsions in these mixes reflects the advantages of:

(i) storing and handling emulsions as binders during mix manufacture;
(ii) safer heating;
(iii) lower heating costs; and
(iv) reduced delays.

In general, stockpile mixes are emulsified cut-back mixes where the emulsion allows mixing and coating of aggregate and the cutter stock is responsible for workability. Dense-graded mixes generally require higher levels of cutter stock for effective mixing and can remain quite "tender" or fluid unless low flash point solvents are employed.

Stockpile mixes using low solvent emulsions may retain their workability by skinning over to "seal" the mix against environmental emulsion break. These mixes require very stable emulsions which in turn require extensive mixing and optimum environmental conditions for cure of the mix at the time of use.

The setting and breaking characteristics of emulsion binders in mixes is influenced by heat as well as by cutter stocks. Varying degrees of heating of emulsion or aggregate or both during placement or manufacture of mixes can be employed to contribute to workability or break.

Use of combinations of heat and low volumes of cutter stocks can produce a range of emulsion mixes appropriate to field application situations, which should include available lay-down equipment.

Where the use of cutter stocks in high enough quantities or of cutter stocks of sufficiently low flash point for good control of these mixes is prohibited, stockpile mixes have been replaced by hot mixes. Experience with site-mixed emulsion mixes for stockpiling has been limited.

6. Chipsealing

6.1 Single-Coat Seals
6.2 Two-Coat Seals
6.3 Three-Coat Seals

Chipsealing applications employ a wide variety of emulsions with different handling and setting characteristics to accommodate all aggregate grades in single- and multiple-coat seals. Cationic emulsions have generally replaced anionic emulsions but, where there is a cost advantage, the use of anionic emulsions may be equally effective. Use of anionic high-float emulsions may overcome run-off problems associated with the high application rates that are used in some regions. Polymers may also be used as "bodying agents" or viscosity builders as well as for their performance property enhancement.

7. Fine Aggregate, Maintenance Sealing

7.1 Texturising
7.2 Void Filling
7.3 Lock Coat

Use of fine aggregates and emulsion for thin surface treatments such as re-texturising, void filling or lock coating, require medium- to fast-setting emulsions. Control of curing is enhanced by rolling in these applications as they have a high aggregate surface to make contact with the binder.

8. Construction Mixes
8.1 Soil Stabilisation

The use of emulsions in construction has been limited to stabilisation of basecourses and tack-coating applications (see Tack Coating). Emulsions are effectively used to stabilise poor quality soils and reduce construction costs associated with quarrying, crushing and cartage of road metal. Incorporation of binders into soils is done with a wide variety of high- and low-shear mixing equipment, and requires a variety of mixing grade emulsions.

9. Thin Surfacing Mixes
9.1 Slurry Seals
9.1.2 Hand Laid
9.1.3 Machine Laid
9.2 Rut Filling
9.3 Cold Overlays Machine Laid
9.3.1 Open-graded
9.3.2 Dense-graded

The use of emulsion mixes for thin surfacing and sealing applications (12mm) is significantly increasing because of the development of greatly improved emulsion-mixing technology.

Emulsion slurry sealing is preferred in urban areas where windscreen damage, unacceptable chip contamination of property, and unnecessarily coarse surface textures result from conventional sealing operations. Emulsion slurry mixes for filling wheel ruts along heavily trafficked carriageways are also effective. The cost effectiveness of these mixes is associated with reduced equipment requirements and improved long-term serviceability of applications. Slurry and thin surface mix applications for surfacing and maintenance problems employ the most sophisticated emulsion technology in terms of emulsion chemistry, setting characteristics and shear susceptibility.

10.	Reconstruction Mixes	Mix-in-place travel plants which pulverise and remix deteriorated pavements with new emulsified binder are being used to improve efficiency in material conservation. This emulsion mixing technology is also being used to reconstruct surface layers of failed seals into stabilised bases for resealing. To date this type of process has not been evaluated in New Zealand.
10.1	Cold Recycling	
10.2	Cold In-situ Recycling	

APPENDIX 2 BITUMEN EMULSION USE BY APPLICATION, AREA, & SPECIFIED PRODUCT, IN NEW ZEALAND TERRITORIAL REGIONS, DERIVED FROM TRANSIT NEW ZEALAND RAMM DATABASE

Year	Ref. No.[1]	Application[2]	Area (m^2)	Specified Product[3]
Region 1 : Northland				
87/88	7.2	VOID FILL GR. 6	1612	CQ60
88/89		NO DATA		
89/90	7.1	TEXTURISING GR. 6	2050	CQ60
Region 2 : Auckland				
87/88	7.2	VOID FILL GR. 5	1074	CQ60
	6.1	SECOND COAT SEAL GR. 5	58162	CQ60
88/89	7.1	TEXTURISING GR. 5	11180	CQ60
	7.2	VOID FILL GR. 6	28665	CQ60
	7.3	LOCK COAT GR. 6	50055	CQ60
89/90	7.2	VOID FILL GR. 6	85675	CQ60
90/91	7.1	TEXTURISING GR. 6	7283	CQ60
Region 3 : Waikato				
87/88	7.2	VOID FILL GR. 6	279976	AQ55
	7.2	VOID FILL GR. 5	8902	AQ55
88/89	7.2	VOID FILL GR. 6	247639	AQ55
	7.3	LOCK COAT GR. 6	3671	AQ55
	5	OGEM GR. 6	5910	TNZ

1 Ref. No. — reference numbers correspond to applications (i.e. uses) listed and defined in Appendix 1.

2 Application — see Appendix 1 for definitions. Abbreviations are:

OGEM — Open graded emulsion mix
GR — Grade
FC — Friction course

3 Specified Product — Abbreviations for bitumen emulsions are:

CQ Cationic quick-breaking emulsion
e.g. CQ65 = Cationic quick-breaking bitumen with 65% minimum binder content
AQ Anionic quick-breaking emulsion
e.g. AQ55 = Anionic quick-breaking emulsion with 55% minimum binder content
CRS-1 Cationic rapid setting ≥ 55% residual binder
CRS-2 Cationic rapid setting ≥ 63% residual binder

Region 3 : Waikato (contd)				
Year	**Ref. No.[1]**	**Application[2]**	**Area (m^2)**	**Specified Product[3]**
89/90	5	OGEM GR. 6	2030	TNZ
	7.2	VOID FILL GR. 6	70038	CRS-2
	7.2	VOID FILL GR. 5	102577	CRS-2
	7.1	TEXTURISING	7310	CRS-2
90/91	7.2	VOID FILL GR. 5	78910	CRS-2
	6.3	LOCK COAT GR. 5	35020	CRS-2
	6.2	TWO-COAT SEAL, GR. 3, GR. 5	22864	CQ65
	6.2	TWO-COAT SEAL, GR. 5, GR. 3	10528	CQ65
	6.2	TWO-COAT SEAL, GR. 5, GR. 5	2500	

Region 4 : Bay of Plenty				
Year	**Ref. No.[1]**	**Application[2]**	**Area (m^2)**	**Specified Product[3]**
87/88	7.2	VOID FILL GR. 6	166150	?AQ55
88/89		NO DATA		
89/90		NO DATA		
90/91	9	SLURRY SEAL	22204	
	7.2	VOID FILL GR. 5	58543	
	6.1	SECOND COAT SEAL GR. 5	5200	
	7.3	LOCK COAT, GR. 5	12528	
	6.2	TWO-COAT SEAL, GR. 3, GR. 5	12898	CQ70

Region 5 : Gisborne				
Year	**Ref. No.[1]**	**Application[2]**	**Area (m^2)**	**Specified Product[3]**
87/88	7.2	VOID FILL GR. 6	6398	
88/89	7.2	VOID FILL GR. 6	29864	
89/90	7.2	VOID FILL GR. 6	14463	

Region 6 : Hawke's Bay				
Year	**Ref. No.[1]**	**Application[2]**	**Area (m^2)**	**Specified Product[3]**
87/88		NIL		
88/89	7.2	VOID FILL GR. 6	7969	AQ55
89/90	6.1	RESEAL GR. 3	2563	
	7.1	TEXTURISING GR. 5	6100	

Region 7 : Taranaki
Nil

Region 8 : Wanganui/Manawatu				
Year	**Ref. No.[1]**	**Application[2]**	**Area (m^2)**	**Specified Product[3]**
87/88	6.1	RESEAL GR. 5	76542	
	6.1	RESEAL GR. 6	4416	
	7.2	VOID FILL GR. 6	24812	
	7.1	TEXTURISING GR. 6	136902	
88/89	7.1	TEXTURISING GR. 5	19635	
	7.1	TEXTURISING GR. 6	120960	
	6.1	RESEAL GR. 4	17599	
	7.2	VOID FILL GR. 6	179190	AQ55
	6.2	TWO-COAT SEAL, GR. 3, GR. 6	2880	
	7.2	VOID FILL GR. 5	11424	
	6.1	SECOND COAT SEAL GR. 6	3820	
89/90	5	OGEM	9840	
1/4-30/6	6.1	SECOND COAT SEAL GR. 4	2583	CRS70
	6.2	TWO-COAT SEAL GR. 6	32418	
	7.2	VOID FILL GR. 6	44983	
	6.1	RESEAL GR. 4	19893	CRS-2
	6.1	FIRST COAT SEAL GR. 4	1100	CRS-2
	7.1	TEXTURISING GR. 6	41234	
90/91	7.1	TEXTURISING GR. 6	8625	
1/7-30/6	7.3	LOCK COAT GR. 6	986	
	6.1	RESEAL GR. 3	37641	

Region 9 : Wellington				
Year	**Ref. No.[1]**	**Application[2]**	**Area (m^2)**	**Specified Product[3]**
87/88	7.2	VOID FILL GR. 5	38700	
	7.2	VOID FILL GR. 6	19350	AQ55
	7.2	SECOND COAT SEAL, VOID FILL GR. 6	3861	
88/89	7.1	TEXTURISING GR. 5	11000	CQ67
	7.2	VOID FILL GR. 5	84174	CQ67
	7.2	VOID FILL GR. 6	97859	
	7.2	SECOND COAT SEAL, VOID FILL GR. 6	9867	
89/90	7.2	VOID FILL GR. 5	35300	
	7.2	VOID FILL GR. 6	74660	
90/91	7.1	TEXTURISING GR. 6	20331	
	7.2	VOID FILL GR. 6	42183	

Region 10 : Nelson/Marlborough				
Year	**Ref. No.[1]**	**Application[2]**	**Area (m^2)**	**Specified Product[3]**
87/88	7.2	VOID FILL GR. 5	30893	
	7.1	TEXTURISING GR. 5	720	
88/89	5	OGEM GR. 5	2015	
	7.3	LOCK COAT GR. 4	2733	
	6.2	TWO-COAT SEAL, GR. 3, GR. 5	9015	

Region 11 : Canterbury				
Year	**Ref. No.[1]**	**Application[2]**	**Area (m^2)**	**Specified Product[3]**
87/88	6.1	RESEAL GR. 6	75204	
	5	OGEM 10 mm	330	
	5	OGEM 6 mm	2977	
88/89	5	OGEM GR. 3?	1432	
	6.3	DRAG SEAL, GR. 3, 4, 5	7102	
	5	OGEM GR. 6	8791	
	5	OGEM GR. 2	185	
	5	OGEM GR. 5	15844	
	5	FC GR. 5	218	
	5	FC GR. 6	1592	
	5	OGEM 10 mm	14735	
89/90	6.2	TWO-COAT SEAL GR. 5	114347	
	6.1	RESEAL GR. 5	29583	
90/91	6.2	TWO-COAT SEAL GR. 6	200	

Region 12 : West Coast				
Year	**Ref. No.[1]**	**Application[2]**	**Area (m^2)**	**Specified Product[3]**
89/90	5	OGEM GR. 5	4270	

Region 13 : Otago				
Year	**Ref. No.[1]**	**Application[2]**	**Area (m^2)**	**Specified Product[3]**
87/88	5	OGEM 6 mm	6440	
	6.1	RESEAL GR. 5	3960	
	6.2	TWO-COAT SEAL, GR. 4, GR. 6	15022	
	5	OGEM 14 mm	3515	
	6.2	TWO-COAT SEAL, GR. 3, GR. 5	25753	
	6.1	RESEAL GR. 3	5120	

Region 13 : Otago (contd)				
Year	**Ref. No.**[1]	**Application**[2]	**Area (m^2)**	**Specified Product**[3]
88/89	6.1	RESEAL GR. 5	23680	
	6.2	TWO-COAT SEAL, GR. 5, GR. 3	7999	
	6.2	TWO-COAT SEAL, GR. 4, GR. 6	15928	
	5	OGEM 6 mm	12320	
	5	OGEM 14 mm	3026	
	5	OGEM 8 mm	1040	
	9	SLURRY TYPE 2	2025	
	9	SLURRY GR. 3	2850	
89/90	6.2	TWO-COAT SEAL, GR. 5, GR. 3	26502	
	6.1	RESEAL GR. 5	17168	
90/91	6.1	RESEAL GR. 5	20390	
	9	SLURRY, TABLE 2	1650	
	6.2	TWO-COAT SEAL, GR. 3, GR. 5	13090	
	5	OGEM GR. 3	9200	
Region 14 : Southland				
Year	**Ref. No.**[1]	**Application**[2]	**Area (m^2)**	**Specified Product**[3]
87/88	7.1	TEXTURISING GR. 6	29490	
	6.1	RESEAL GR. 5	12665	
88/89	5	FRICTION COURSE 8 mm	7500	
	6.1	RESEAL GR. 6	12920	
	6.2	TWO-COAT SEAL, GR. 3, GR. 5	20700	
	7.1	TEXTURISING GR. 6	8245	
89/90	7.1	TEXTURISING GR. 5	113172	CQ70
	6.1	RESEAL, GR. 3, GR. 5	52791	CQ70
	6.1	RESEAL GR. 5	33964	CQ70
	6.1	FIRST COAT SEAL GR. 5	1575	
Total for New Zealand			3521437	

Appendix 2.1 Use (by area in m^2) of bitumen emulsion in each New Zealand territorial region, for maintenance applications.

Maintenance Application	7.1* Texturising				7.2* Void Filling				7.3* Lock Coating	
Region/Year	87/88	88/89	89/90	90/91	87/88	88/89	89/90	90/91	88/89	89/90
1. Northland			2050		1612					
2. Auckland		11180		7283	1074	28665	85675		50055	
3. Waikato			7310		288878	247639	172615	78910	3671	35020
4. Bay of Plenty					166150			58543		12528
5. Gisborne					6398	29864	14463			
6. Hawkes Bay			6100			7969				
7. Taranaki										
8. Wanganui/ Manawatu	136902	140595	41234	8625	24812	190614	44983			986
9. Wellington		11000		20331	61911	191900	109960	42183		
10. Nelson/ Marlborough	720				30893				2733	
11. Canterbury										
12. West Coast										
13. Otago										
14. Southland	29490	8245	113172							
TOTALS (m^2)	167112	171020	169866	36239	581728	696651	427696	179636	56459	48534

* Reference numbers correspond to applications (i.e. uses) listed in Appendix 1.

Appendix 2.2 Use (by area in m^2) of bitumen emulsion in each New Zealand territorial region, for sealing applications.

Scaling Application	6.1* Single-Coat Seal				6.2* Two-Coat Seal				6.3* Three-Coat Seal		
Region/Year	87/88	88/89	89/90	90/91	87/88	88/89	89/90	90/91	87/88	88/89	89/90
1. Northland											
2. Auckland	58162										
3. Waikato								35892			
4. Bay of Plenty				5200				12898			
5. Gisborne											
6. Hawkes Bay			2563								
7. Taranaki											
8. Wanganui/Manawatu	80958	21419	23576	37641		2880	32418				
9. Wellington											
10. Nelson/Marlborough						9015					
11. Canterbury	75204		29583				114347	200		7102 (Drag Seal)	
12. West Coast											
13. Otago	9080	23680	17168	20390	40775	23927	26502	13090			
14. Southland	12665	12920	88330			20700					
TOTALS (m^2)	236069	58019	161220	63231	40775	56522	173267	62080		7102	

* Reference numbers correspond to applications (i.e. uses) listed in Appendix 1.

Appendix 2.3 Use (by area in m^2) of bitumen emulsion mixes in each New Zealand territorial region.

Bitumen Emulsion Mix Application	5* Open-Graded Mixes				8* Friction Courses	9.1* Slurry Seals	
Region/Year	87/88	88/89	89/90	90/91	88/89	88/89	90/91
1. Northland							
2. Auckland							
3. Waikato		5910	2030				
4. Bay of Plenty							22204
5. Gisborne							
6. Hawkes Bay							
7. Taranaki							
8. Wanganui/Manawatu			9840				
9. Wellington							
10. Nelson/Marlborough		2015					
11. Canterbury	3307	40987			1810		
12. West Coast			4270				
13. Otago	9955	16386		9200		4875	1650
14. Southland					7500		
TOTALS (m^2)	13262	65298	16140	9200	9310	4875	23854

* Reference numbers correspond to applications (i.e. uses) listed in Appendix 1.

APPENDIX 3 BITUMEN EMULSIONS SPECIFIED FOR USE IN A NUMBER OF APPLICATIONS, IN THE SEVEN TRANSIT NEW ZEALAND REGIONS.

Application* / TNZ Region	7.1 Texturising Seal	7.2 Void Fill	7.3 Lock Coat	6.1 Single-Coat Seal	6.2 Two-Coat Seal	6.3 Three-Coat Seal	5 OGEM	9 Slurry Seal
1. Auckland	CQ60	CQ60	CQ60	CQ60			FC	
2. Hamilton	CQ65 / CRS2	CQ65 / CRS2	CQ65 / CRS2	CQ70 / CRS2	CQ70 / CRS2		TNZ	
3. Napier								
4. Wanganui	CQ AN	CQ AN	CQ AN	CRS2	CRS2		TNZ	
5. Wellington	/ CQ68	/ CQ68	/ CQ68					
6. Christchurch		CQ67	CQ55	CQ67	CQ67	CQ67	TNZ	IA
7. Dunedin	CQ70	CS60		CRS2 / CQ70	CRS2 / CQ70		SPEC <u>200</u> CMS 2-H	Type I Type II Type III

Abbreviations on following page

Appendix 3 Abbreviations

Ref. No. — reference numbers correspond to applications (i.e. uses) listed in Appendix 1.

Application — see Appendix 1 for definitions. Abbreviations are:

OGEM	-	Open graded emulsion mix
FC	-	Friction course

Specified Product — Abbreviations for bitumen emulsions are:

CQ		Cationic quick-breaking emulsion
e.g. CQ65	=	Cationic quick-breaking bitumen with 65% minimum binder content
AQ		Anionic quick-breaking emulsion
e.g. AQ55	=	Anionic quick-breaking emulsion with 55% minimum binder content
CRS-1		Cationic rapid setting ≥ 55% residual binder
CRS-2		Cationic rapid setting ≥ 63% residual binder
SPEC 200		Dunedin City Council Fulton-Hogan emulsion specification
CMS 2-H		Cationic medium setting, 80/100 bitumen
/		
AN		Anionic
CS 60		Cationic slow setting, 60% residual bitumen
TNZ		Transit New Zealand
IA		Christchurch City Council Slurry Designation
Type I }		
Type II }		correspond to aggregate gradations used in slurry seal mixes
Type III }		(*International Slurry Surfacing Association Specifications*).