CHAPTER ONE

History of Chipsealing in New Zealand

Chapter 1 History of Chipsealing in New Zealand

Previous page: Laying a first coat chipseal on a New Zealand state highway in the 1970s. From left is a 9-ton 3-wheeled roller, a bitumen distributor and on the right a fan-tailed chip spreader on a short wheel-based tip truck. Photo from NRB (1974)

Chapter 1 History of Chipsealing in New Zealand

1.1 Before Chipsealing

The technique of sealing roads with tar or bitumen binder[1] and stone chip has been used to provide protective waterproof, relatively flexible, road surfaces for wheeled traffic for only the last 175 years. Roman roads that have survived for at least 2300 years were also constructed with protected surfaces, but they were rigid usually made with slabs of stone, over a built-up base (as are today's roads), or bridge-like causeways across soft soils. Remnants of these straight roads include the Appian Way which was begun in 312BC. There is evidence that bitumen was used by Nebuchadnezzar of Babylon to grout stone roads and to waterproof the masonry of his palace (Morgan & Mulder 1995) about 600BC. However, the present use of a bituminous binder in a road pavement started with tar macadam in Nottinghamshire as recently as 1830. (Tarmac later became a general term for a tar- or bitumen-bound material used for a pavement, especially the surface layer of pavements for aircraft runways.)

1.2 Chipsealing comes to New Zealand

Two advances made in the latter part of the 19th century encouraged sealing roads with protective surfaces in New Zealand. One was of the increased production of coal gas for lighting and heating, and its by-product coal tar. The other was the automobile which required smoother and safer surfaces than the rutted gravel surfaces which had previously provided the needs of lighter horse-drawn traffic (Figure 1-1).

Figure 1-1 Chipsealed roads made a great improvement to travel in New Zealand, as "up to the axles in mud" was commonplace in the early days of transport. Right image shows a horse-drawn wagon bogged down on its way to Frederic Truby King's farm at Tahakopa, South Otago (c. 1910s).

Photos courtesy of Alexander Turnbull Library, ATL PAColl-5932-14 (left); ATL F-46755-1/2, PAColl-6097-001 (right)

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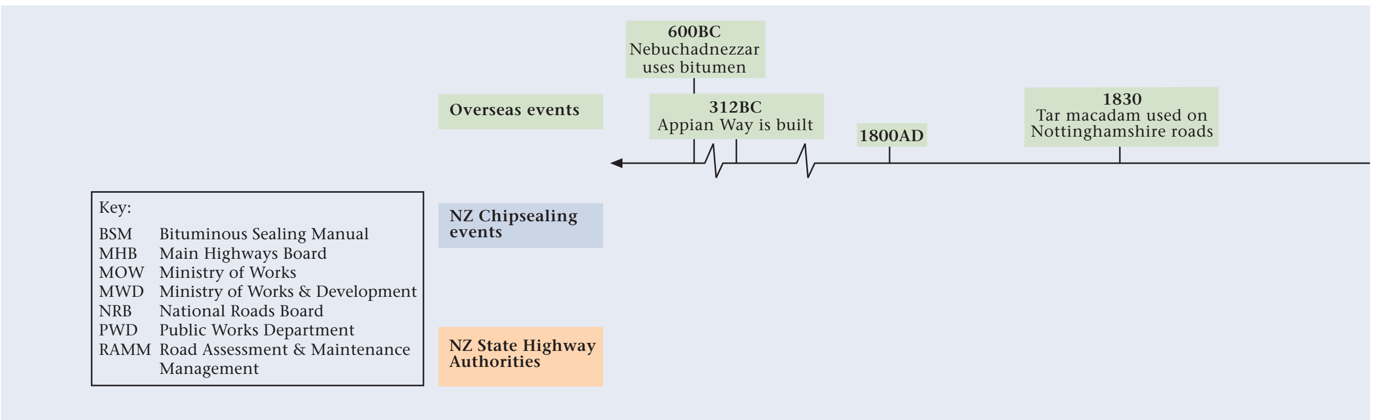
[1] Terms relating to roads and chipsealing are explained in Chapter 3, and in the Glossary.

A contributing reason to the wide use of chipsealing in New Zealand in the early 20th century was its lower production costs. Chipseals could be constructed using simple plant and some local materials. It was a process which could be applied over a conventional water-bound macadam pavement (which then became the basecourse of stones of the pavement), yet provided enough flexibility to resist cracking under normal service by traffic. It was and remains simpler and cheaper, requiring much less energy than making the bitumen-bound macadams used in the northern hemisphere for which the stone chip (or aggregate) and the binder have to be heated together and for which specialist mixing plant is required. As a result, the technique of chipsealing roads has been developed to a high degree and consequently New Zealand's roading engineers are acknowledged to be among the world leaders in this field.

From about 1880 in New Zealand, tar from the local gasworks was sprayed over roads or footpaths and covered with locally sourced chips to make a dust-proof and waterproof surfacing. The technique was to hand-spray about a quarter of a gallon per square yard (about 1.35ℓ/m^2) of binder over the compacted basecourse. This produced a film of binder about 0.05 inches (1.35 mm) thick. It was covered with bigger than sand-sized gravel or crushed chips, and the seal was compacted with a roller. Gradual refinement in techniques evolved.

1.3 Principles and Philosophy of Chipsealing

During the early 1930s, development of the automobile and increase in traffic volumes created a demand for improvement in the quality of road surfaces. About this time, testing and experimenting with aggregates and bitumen were carried out in an effort to be more quantitative, and less dependent on the skill of the on-site manager, overseer or foreperson, and on their eye for best practice.



A more scientific approach to the design of the chipseal road surface was needed. When F.M. Hanson presented his paper *Bituminous surface treatment of rural highways* to the Conference of the NZ Society of Civil Engineers, in 1935, he made the first steps to quantify the chipseal concept.

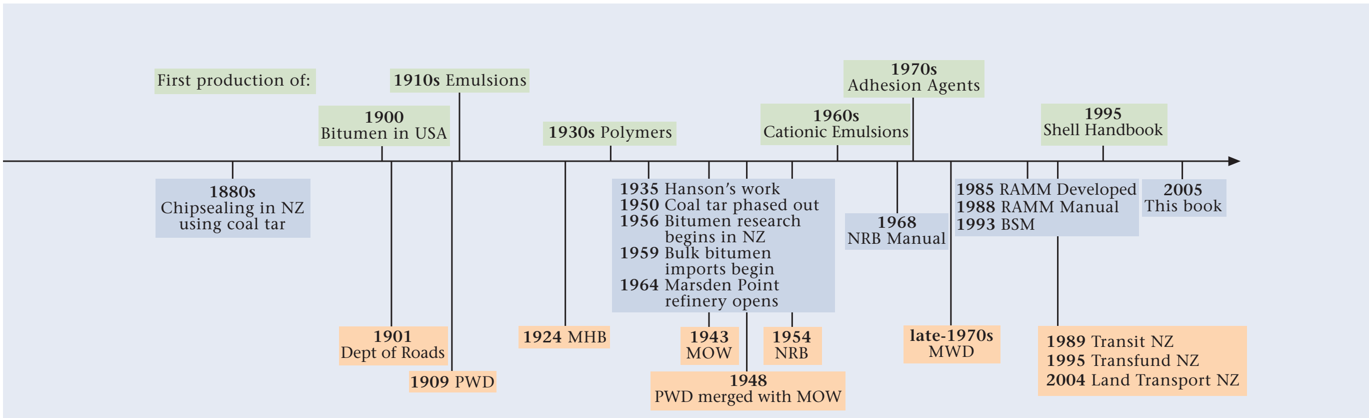
Based on his methodical approach for this paper, chipsealing as we know it today was established. The precept was that the rate of application of the binder should be designed to rise 2/3rd up the height of the stone chips, to leave a non-skid, non-glare stone surface to take the wear and stress imposed by traffic.

Hanson's principles relating to the theory of surface sealing (Figure 1-2) were summarised in the National Roads Board (NRB) 1968 *Manual of sealing and paving practice*, and are quoted here:

1. *When sufficient chips are placed on a seal binder to ultimately bed into a single layer in shoulder to shoulder contact, the percentage of voids in the initially laid loose state is approximately 50%. This is reduced to about 30% by construction rolling, and to 20% by traffic compaction.*
2. *The amount of binder required bears a definite relationship to the volume of voids in the cover stone aggregate; the quantity should be such that between 65 and 70% of the voids in the finally compacted layer of sealing chips are filled with binder.*
3. *The average depth of the layer of stone chips forming the cover coat, after construction and traffic compaction is approximately equal to the average least dimension (ALD) of the chips used.*

Although the principles that Hanson promoted are still current, refinement to the values of voids has been made as more information has been gathered.

The whole basis of Hanson's theoretical approach relied on the concept that the percentage of voids in the loose state as initially laid was 50%. This concept was verified by the



following experiment carried out for Hanson (by Mr Tom McLoughlin who was a public works overseer and later became a prominent sealing contractor). A 44-gallon (200-ℓ) drum was filled with the smallest single size chips available, then water was poured into the drum until it was full. The volume of water poured into the drum filled the voids between the chips, and equalled 50% of the volume of the drum. This established that the percentage voids in the loose chips was 50%. The experiment was repeated using each of the other chip sizes and the results always came out at 50%.

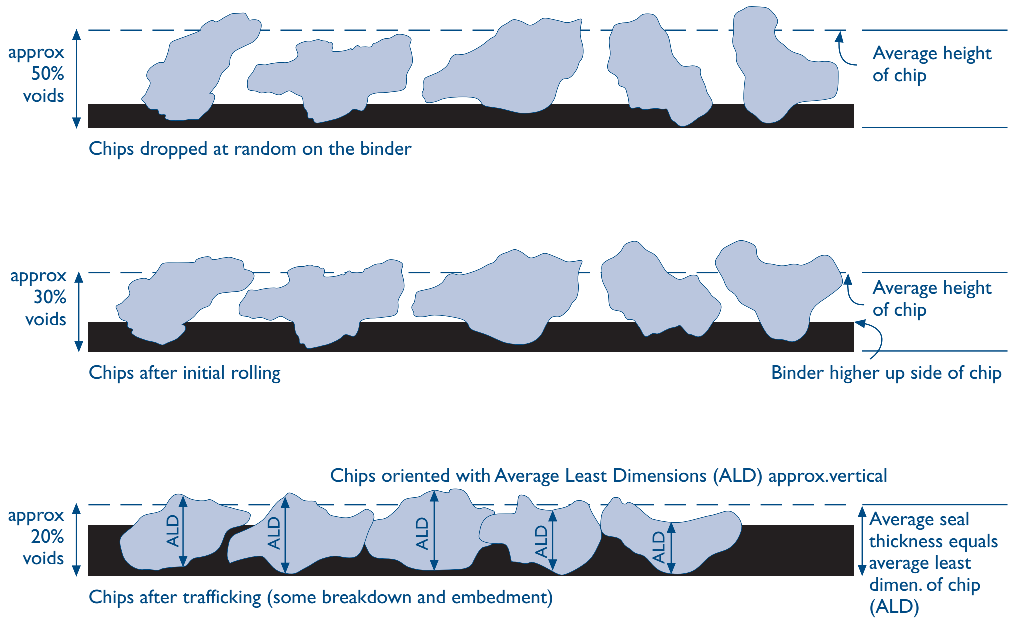


Figure 1-2 States of embedment of sealing chips in binder (from NRB Manual 1968).

These measurements demonstrated that the physical properties of packing and the 50% voids between chips were independent of the size of chip. To achieve this end result, chips need to be near-cubical (a shape which became possible to attain when the impact crusher came into use), with low (<1.1%) fines, and with little silt or clay on the chip surfaces (i.e. high cleanness value).

Later Hanson (1948) reasoned that a scientific and rational approach to road construction was essential to overcome the failure of roads built on clay and silt foundations, and the general deterioration caused by increasing axle loads and tyre pressures. Otherwise overdesign with the accompanying waste of money, or underdesign with costly failures, would continue to be applied.

This Chapter outlines some of the changes made to binders and stone chips in order to better achieve these basic principles on the road. But since the 1970s other factors have changed. The stresses on high traffic volume roads have increased caused by heavier vehicles (up to 43 tonnes gross laden weight, or 42.3 tons), the introduction of power steering and braking, single drive axles, higher engine power and higher speeds. These began pushing the technology to its limit. The demands have led to the development and use of more shear-resistant chipseal systems (e.g. modified binders, multicoat seals). The research that continues today on developing relevant algorithms for modern bituminous-surfacing seal design is described in subsequent chapters of this book. Where the demands are too high for chipseals, other surfacing techniques such as hot mix asphalt have to be employed, and only brief reference is made to these techniques in this book.

Sealed roads were originally confined to towns but the total length of chipsealed road steadily increased each year until by 2004 the length of state highways under chipseal recorded in Transit NZ's annual statistics report was 10,837 km, with the last 20 km to Cape Reinga still to be sealed. This is only 12% of the total length (including state highways) of the road network in New Zealand, which now totals 92,760 km. The Road Controlling Authorities (RCAs) who administer the other 81,923 km or 88% are the 74 Local Authorities (i.e. City Councils and District Councils).

1.4 Changes in Binder Materials

Coal tar

Coal tar is a by-product from local gasworks and was the earliest and only binder used in New Zealand until about 1910, when bitumens for roading use first became available. With about 65 gasworks around the country it was generally available. Most New Zealand tar was undistilled and was hazardous to work with. Workers, such as the spray operator on the hand spraybar, could suffer skin burns from the high sulphur content and other chemicals in the tar, and it was known to be carcinogenic. Distilled tar that came mainly from England was more benign and also had a longer life in the pavement. However substantial processing was required to produce a tar having good road-making properties, and many works did only minimal processing. Their tars were suitable for use as primers which were exposed for only a short time before being covered by the next seal coat, and the requirements were less stringent and far easier to meet.

This source was dwindling by the mid-1950s by which time only four or five gasworks were producing roading tar, although imported English coal tar was used in Central Otago as late as 1959 for first coat sealing on state highways.

Bitumen

Bitumen is the heavy residue obtained from refining crude oil. Roading grade bitumen had been first produced in the United States around 1900, and it came into use in New Zealand as a more durable and less temperature-sensitive material than coal tar about 1914, just before World War 1. The first bitumen to be applied to a pavement in New Zealand was undertaken by Sir Russell Matthews in 1914 in New Plymouth. The bitumen had been imported in wooden stave barrels from the Standard Oil Company from Pennsylvania, USA. Until the early 1930s, crude oil products (penetration grades used for chipsealing, emulsions and hot mixes, and more fluid road oils) were imported mainly from the United States. The barrel staves made a good fuel for the decanters or heaters (tar kettles) which supplied bitumen to the sprayers (Figure 1-3) and were horse-drawn (Figure 1-4). A rope extended along the side of the heater to the horse-hitching harness so that the horse could be released if the bitumen caught fire. This escape mechanism was used in the case of explosion or fire so if the horse bolted it did not drag the unit up the street leaving a trail of catastrophes for both workers and bystanders.

Figure 1-3 This bitumen heating kettle (left) being used in Taranaki was the way to heat bitumen in the 1920s. The fire, stoked with staves from empty bitumen barrels, was in the firebox under the kettle. The firebox gases passed around all sides of the kettle. Photo courtesy of John Matthews, Technix Group Ltd

As if the task was not hazardous enough, the bitumen was pumped by a hand-operated gear pump, and that was a very unpleasant occupation for the person standing alongside the uninsulated surfaces of the tar kettle.

Supplies of lighter penetration grade bitumens, road oils and some cutbacks came from California and Mexico, and were transported in 44 gallon (200 ℓ) steel drums (which later found an interesting end use, see box). They were the main sources until after World War 2, about 1945, after which sources widened to include the Middle East oilfields.

Figure 1-4 Draughthorse-drawn bitumen hand sprayer ready for sealing the main street of Opunake, Taranaki, in the 1920s. Photo courtesy of Feaver Collection, Puke Ariki Museum Archives, New Plymouth

Later containers were steel drums and, rather than waste them, at least one contractor had a sideline business recycling them. He used equipment that peeled the ends off the drums (similar to a can opener), opened up the cylindrical part of the drum which was then passed through a flat roller, and finally through a corrugated roller. The product, bitumen-coated corrugated sheets, proved very popular for sheds and other buildings, particularly in the country.

As road building activity increased, annual bitumen use doubled between 1950 and 1960 to about 60,000 tons (about 60,960 tonnes). It levelled out at about 100,000 tons (about 101,600 tonnes) per year until 1980. To cope with this increase, and in anticipation of refining oil in New Zealand, the first imports of bitumen in bulk tankers were in 1959 from Venezuela. In 1964, the New Zealand Refining Company's plant at Marsden Point, near Whangarei, opened and took over supply almost totally, with distribution to a total of nine ports around New Zealand. To maintain consistency in meeting the fairly demanding requirements set by Specification (see box) NRB M/1 (now TNZ M/1:1995) and to be within the refinery's capability, crude oil generally came from a single Middle East oilfield which could be accessed by the main New Zealand oil companies. Its higher price was a relatively small disadvantage compared to the high transport costs of importing the bitumen.

Specifications and Notes contain best practice for the construction and maintenance of roads, including specifications for materials, paving, surfacings, road formation, equipment, traffic control, and quality assurance. In this book, most of the specifications are dated to indicate the versions that are referred to. Specifications referred to in contract and other works documents may not be dated to indicate that the latest version available is the one that applies. Specifications and Notes have been produced by the various government departments which have been responsible for the nation's roads over the last 105 years.

Extensive research into bitumen properties began at Dominion Laboratory (forerunner of Chemistry Division, Department of Scientific & Industrial Research) in 1956, and continues today mainly at Opus Central Laboratories, but also at the laboratories of some of New Zealand's roading contractor companies. Much of the information given in Chapters 4, 8 and 9 is based on this New Zealand research.

Bulk bitumen created some logistical transport problems that had a major effect on the bitumen contracting industry and road making generally. Initially the bitumen was transported by ship to bulk storage facilities at the ports of Auckland, Wellington and Lyttelton. Transport by road in the early 1960s was limited by law to 90 miles (145 km) from the port facility. If bitumen had to be carried beyond that 90-mile limit, it had to be transported by rail tankwagons that were purpose-built. The rail wagons were fitted with flame tubes that could be fired by demountable burners for heating the bitumen. However, purpose-built spray tankers were exempt from this 90-mile restriction, and soon some contractors had fitted pumps and sprayer equipment to their bulk-bitumen delivery tankers in order to circumvent these regulations.

Oil industry policy was to supply bitumen heated only to a pumpable viscosity (a temperature which is too cold for spraying). In practice this meant that each independent contractor had to have dedicated heating plant to raise the bitumen to spraying temperature. This discouraged small contractors from becoming involved, causing instability in the bitumen contracting industry over many years, and affecting the rate of road building.

Another problem arising from importing crude oil for processing at the refinery was the need to balance the barrel, i.e. for every barrel of crude oil refined there had to be a market for each by-product (e.g. for kerosene, petrol, diesel, bitumen). This meant that each oil company was required to balance the marketing of its products with the yield from the crude oil imported.

Bitumen Emulsions

Bitumen emulsions were first used in New Zealand about 1910, and their use today is detailed in Sections 8.3 and 11.4. Until the mid-1960s only one type of emulsion was available for roading. It is called 'anionic' because the droplets of emulsion have negative charges, and it was manufactured with 55% to 60% water content. This created an on-road viscosity that is very much lower than that of conventional spraying-grade straight-run or cutback bitumen. Thus application rates had to be kept quite low to avoid the binder running into the side water channels before the chip was applied. Also the low application rates meant that only small chip sizes could be used in single coat seals. Foaming often occurred while blending the bitumen and water to make these emulsions.

By the mid-1960s new technology and chemicals had become available that allowed production of the alternative 'cationic' type of bitumen emulsion (in which the dispersed droplets of bitumen carry positive surface charges) at about the same cost as anionic emulsion. Another point in their favour is that they have higher on-road viscosities immediately after spraying. These advantages of the cationic type over anionic make it the main type now used in New Zealand.

Rubber and Polymers

Natural rubber and synthetic polymer compounds were first trialled in the 1930s. They were found to make the binder less susceptible to softening at high temperatures, less brittle at low temperatures, and more ductile. These modified binders that are now being used on more heavily trafficked routes to achieve a longer seal life are covered in Sections 8.4 and 11.5 of this book.

Initially introduced in the mid-1960s, based on research by the Malaysian Natural Rubber Bureau and others, rubber latex (i.e. natural rubber as an emulsion) or semi-vulcanised crumb rubber were two more commonly used additives.

Totally synthetic polymers came into use in the early 1980s. Their formulation for easier blending allows higher proportions to be added that give better performance properties than are achieved with natural rubbers.

Precoating

Precoating sealing chips improves some adhesive properties of the binder and is covered in Section 8.2.3. Initial precoating trials using imported petrochemical tar were carried out about 1964, and trials with locally produced primer from coal tar followed shortly afterward. In addition to promoting adhesion in wet conditions, tar primer precoating was also very effective in countering effects of dust on chips as it penetrates through to the chip surface.

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Precoating was originally carried out by spraying the primer onto the stockpile, and then mixing the stockpile. This inefficient method of mixing has since been replaced by the mobile precoating plant. Use of precoating decreased markedly in the mid-1970s when chemicals (called adhesion agents) that improved adhesion of chips to the binder came on the market.

Adhesion Agents

Adhesion agents improve the development of adhesion between the binder and the damp chips by causing the binder to preferentially 'wet' the chip, as explained in Chapter 8.2. Chip loss that occurs following rain on a new seal was a common problem in the 1960s, and so the use of adhesion agents gained popularity.

Laboratory investigation of adhesion agents was followed by site trials north of Auckland in 1956-57. The procedure came into general use in the 1970s, eventually replacing the use of precoating. Their continued use has proven to be good insurance against chip loss which more than outweighs their cost.

Priming

Priming is the application of a low viscosity coal tar or bitumen, and was widely used from the 1930s to 1950s to improve the top surface of a complete 'ready to seal' basecourse. The less refined coal tars were used extensively as a priming treatment as they penetrated the gravel basecourse, producing optimal conditions for the application of the first seal coat.

Until the mid-1950s, aggregates used in basecourse construction were generally not uniform in grading, and usually damp, dusty, or dirty with clay and silt. In such less than ideal conditions, and before adhesion agents were available, primers applied as prime coats were very successful as a means of binding and waterproofing the surface of an unbound basecourse. After the prime coat had cured, the basecourse could then accept a full chipseal consisting of a seal coat of high viscosity binder that could retain chip of the chosen size.

Once tar was no longer produced, cutback bitumen containing around 50% kerosene was used as a primer and, although it proved to be satisfactory, it did not have the same penetrating capabilities of tar. It was also hazardous to use as it has high risks associated with its very low flash point (about 49°C) and high flammability. Now the use of cutback bitumen as a primer is discouraged mainly because of these hazards (which are described in Chapters 2 and 3). Also improvements in the quality of basecourse materials and construction techniques have resulted in cleaner and tighter surfaces on which to seal, which means that prime coats are not needed.

1.5 Changes in Aggregate Materials

In the early days of chipsealing, it was quickly discovered that if graded sandy aggregates were used for cover stone or chip, the binder tended to work its way to the surface. Observation showed that cover chip of a restricted size range produced a good job, and also that angular stones tended to lock into place better than rounded gravel.

When the Main Highways Board (MHB) began issuing specifications in the late 1920s, consensus was that unweathered chip, free of sand, silt and clay, of a defined range of sizes should be used. (The typical size was given as nearly all passing a $^{3}/_{4}$ inch (20 mm) round-hole screen and nearly all retained on a $^{3}/_{8}$ inch (10 mm) round-hole screen.)

Hanson's 1935 recommendations placed considerable emphasis on the use of a single layer of uniform sized chips, even though he was recommending use of much larger chips than we now use 70 years later. Well crushed material was required and river-sourced material before crushing had to be larger than a $1^{1}/_{2}$ inch-diameter circular ring. Cleanness and durability were required of the chips (at source), with maximum wear numerically limited by testing using the tumbling test (Duval Attrition test) or the ball mill test (Los Angeles Abrasion test).

Chip selection was by size (measured by average least dimension (ALD)), shape and uniformity. The surge of sealing work after World War 2 led to more formal categorisation of sealing chip sizes, using Grades A, B and C which had ALDs of 0.50 (12.7 mm), 0.40 (10 mm), and 0.30 inches (7.5 mm) respectively. Specification limits added from time to time through to 1964, to deal with perceived quality shortfalls, led to a worrying proportion of good quality batches of chips being rated as non-complying. Further, as demand for sealing chips grew, use of clean alluvial-sourced aggregates (from which most soft materials have been removed by river action) had to be supplemented with quarry-sourced materials. As these retain less durable fractions (e.g. clays), this meant that quantifying durability and weathering of these chips became necessary tests as well. Problems of stone polishing caused by increased traffic required Polished Stone Value (PSV) limits to be added to the specification.

In 1965, a complete review resulted in a changed specification format, very similar to the present TNZ M/6:2004. It defined Grades 1 (coarsest), 2, 3, 4 (finest), the limits on % sand and clay fractions, and presence of broken faces for chips. As well, two finer grades (Grades 5 and 6) used for voidfilling and similar purposes were added. The development and use of these grades is explained further in Section 8.5.

The 1970's oil shortage affected the amount of bitumen available for sealing in New Zealand. It made the use of smaller chip more attractive as a surfacing, especially as smaller chip is considered to use bitumen more efficiently, although greater skill is required by the operator to use it successfully. Smaller chip also cuts down on road noise and vehicle fuel consumption (by creating less rolling resistance).

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1.6 Changes in Equipment

Advances in engineering technology over the last 50 years have seen some notable improvements and developments to overcome the hazards of the early equipment (see also Chapter 10).

Sprayers

Early chipseal methodology compared to modern methods was quite primitive and based more on experience than research. Before the introduction of spraybars, bitumen was hand sprayed (Figure 1-5), and typical equipment used for hand spraying included:

- Spray lance for spraying direct from the drum;
- Suck-blow sprayer;
- Tankwagons (distributors) fitted with motor-driven pumps and hand-spraying equipment.

Hand spraying became a highly developed skill and good operators needed to have the rhythmic grace and style of a ballroom dancer. In addition they had to be able to vary this rhythm to compensate for any variation in surface texture, and the tanker driver moved the tanker along the road synchronised with the movements of the sprayer operator. Without this synchrony of the driver and the sprayer operator, the quality of the job could be seriously lowered.

Figure 1-5 Most early chipsealing was carried out to keep down dust in the summer and mud in winter. In the 1920s this spray operator in Opunake County was using a hand sprayer with a swinging boom that kept the hose clear of the hot bitumen tank. Photo courtesy of John Matthews, Technix Group Ltd

The pumps on the tankwagons could not be reversed, so once a job was started it had to be kept going until it was finished. So, at 'smoko' time, the lance would be poked back into the tank to keep it warm and prevent blockages. Initially, when fully circulating systems were introduced, the return line went into the top of the tank and the binder flowed down through the vapour space into the tank. When using emulsions this caused aeration with many foam-overs or boil overs, and very messy results. This arrangement has been discontinued and the return line now enters at the bottom of the tank.

Early mechanical spray bars had very unreliable control of transverse or longitudinal distribution, and of the application rates of the bitumen. Blockages were common as well. The first gangbar-operated sprayers (which had the spray nozzles in an interconnected line, like a gang) were not well received by the roading authorities, and hand spraying remained the preferred method of applying bitumen for some time.

Figure 1-6 An old-style bitumen distributor (sprayer). Note the tall handle behind the distributor tank which was used to open and shut the spraybar. Photo courtesy of Laurence Harrow, Opus

Spray nozzle valves were interconnected with a gangbar-lever system to enable all the nozzles to be operated together. All these spray bars were operated manually, and the sight of someone swinging on the lever to turn taps on and off was common (Figure 1-6). The V-jet nozzle has been the most favoured for use on spraybars and, although the quality has significantly improved, they have never been able to produce a uniform spray pattern. To compensate for this, triple overlapping of the nozzle sprays (so that three fans of spray covered each section of the road) was adopted at a very early stage. This arrangement is discussed further in Chapter 10.

Dipping the tank

The task of dipping the tank had to be done to measure the volume of bitumen used before and after a sealing job. It was also done regularly during a sequence of spray runs to determine the actual spray rate of bitumen that was being applied. It involved clambering up to the top of the distributor tank and could be a hazardous job, especially in the poor light of a plant shed at the end of a long hard day's work. There are tales of shortcuts like using a cigarette lighter to peer at the dipstick while holding it over an opened hatch (with the real possibility of an explosion, and not recommended in any Codes of Practice)!

Thermostats

Early thermostats used on tankers had wide temperature differentials and the difference between the cut-off and cut-in temperatures could be as high as 20°C. These had some repercussions as in the following instance. To ensure the temperature would be right for a early morning start, one over-conscientious operator set the temperature 20°C higher than the normal. When he arrived on the Monday morning, flames were licking around the top hatch of the tank.

Heating equipment

Heating equipment has undergone considerable changes since the tarpot days, but nonetheless can be lethal devices.

Flame tube heating – this is heating by direct firing into a burner tube located near the bottom of the tank. The quest for faster heating rates resulted in flame tubes being equipped with burners that had a capacity greater than the rate at which the bitumen could transfer the heat throughout the tank. Flame-tube wall temperatures could reach dangerous levels, and the internal walls of the flame tube would be glowing red hot for some considerable time after the heater was turned off. Spot heating of the tube walls was another problem to watch for.

The main causes of tanker explosions and fires have been a consequence of these tubes becoming exposed to the flammable vapours inside the tank, explained further in Chapter 2.

Research work on flame-tube heating was initiated by the NZ PBCA[2] in the mid-1990s, and maximum heating rates and temperatures (i.e. 350°C) for flame tube heaters were established.

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2 NZ PBCA (NZ Pavement & Bitumen Contractors' Association) is now Roading New Zealand as from 26/06/2004.

Heat transfer oil systems – these systems heat by circulating hot oil via a heating chamber, and then through a tube 'nest' immersed in the bitumen tank. Bulk storage installations continue to use this system but extra care is required if they are to be used in the blending tanks used for cutback bitumen.

Electric elements – these were the preferred and safest option (and still are) for heating bitumen and various types have been used. A low-voltage transformer supplies current through elements comprising mild steel rods, such as reinforcing steel, mounted on insulated supports located near the bottom of the tank. These are safe and reliable provided that the heat rate of the rods is kept low.

Controlling sprayer road speed

In the early days of mechanical sprayers (Figure 1-7), another skill the driver needed was to alter spray rates by altering road speed. The gearing systems of some trucks could not cope with the slow speeds needed for high application rates, and many clutches were burnt out.

Road surfaces with varying textures called for additional skills of observation to achieve acceptable application rates. The overseer walked alongside the tanker observing the road texture ahead of the sprayer and signalled the driver to slow or speed up as required.

Figure 1-7 A 1940s bitumen distributor and hand sprayer, vacuum-filled and pressure discharged, on display at the property of John Matthews, Technix Group Ltd, New Plymouth.

Photo courtesy of John Matthews, Technix Group Ltd

Early calibration of sprayers and uniformity of transverse distribution were checked by placing paint tins underneath each nozzle and measuring the amount collected over a selected time. A more sophisticated method was to run the sprayer over a set of 50 mm-wide absorbent pads to measure the variability in transverse distribution.

Fan-tail chip spreaders

These chip spreaders have fan-tailed shaped rear gates and were generally used on short-wheel-based trucks to allow the tray to be raised high enough in all situations (see Frontispiece). As these trucks were operated in reverse, they were an occupational hazard for the fan-tail operators who had to perform a number of dangerous tasks, e.g. walking alongside the rear of the truck, sometimes on the driver's blind side, and running in to put in dividing plates. Operators were likely to be injured if the driver of the reversing truck could not see them.

Fan-tail spreaders were difficult to operate successfully and the driver had to be very skilful. Also they did not give uniform application, especially on corners. Windows or gaps in the sealing chip had to be spotted and covered by hand-spreading from the back of a truck. In addition to the spotting team, drag brooms were used as a means of redistributing the uneven chip layers. With the advent of roller spreaders in the mid-1960s, chip coverage improved significantly. These days there is less need for drag brooming or spotting and they are seldom used. Kinds of spreaders and rollers are covered in Chapter 10.

The Flaherty Chip Master spreader was imported from the United States in 1960 and, as this machine was driven forwards rather than reversed, both driver and operator were able to see each other. It was safer, but as it was a single purpose machine it never gained general acceptance.

While purpose-built chip-spreading machines are used today, roller spreaders mounted on trucks are the predominant type.

Rollers

At first, 7 or 9 ton (7.11 or 9.14 tonnes) 3-wheel steel rollers were used (without ballast for easy transport and to reduce crushing of the aggregate on the road). Over the years, rollers improved and new models were introduced, such as the 13-ton (13.2 tonnes) rubber-tyred roller which required fewer passes. Now fewer passes are needed and the chip is not crushed but kept at the design size required for the job.

1.7 Changes in Procedures

Asset Maintenance

A problem with chipseal is that it is not permanent. Though relatively flexible, cracks left untreated will let water in and increase the incidence of potholes and deformation. Because wear and weathering require spot repairs and eventual resealing, a deliberate maintenance regime and provision for resealing are needed in the longer term care of a chipseal.

To keep track of the state of the roads and their needs for maintenance and resealing, the database Road Assessment and Maintenance Management System or RAMM was established in 1985. RAMM is an inventory of road assets and of their condition. Its function is to use the inventory and condition to predict short-term treatment needs. The *RAMM Road Condition Rating Manual* (known as the *RAMM Rating Manual* but now out of print) was issued in 1988 by the then National Roads Board, and has been administered by Transit New Zealand since 1989, and uses software supplied by CJN Technologies (2004).

In 1994 the Minister of Transport, in consultation with the Minister of Finance, required all local authorities to have in place a maintenance management system based on RAMM no later than 30 June of that year. As a result, all Road Controlling Authorities (RCAs, i.e. authorities responsible for roading within their jurisdictions) are now using RAMM.

From the mid-1990s, intelligent systems have been implemented in New Zealand that use the RAMM inventory and condition information to predict long-term maintenance needs when developing maintenance Forward Works Programmes (explained in Chapter 5). dTIMS[3] is the software now used for pavement deterioration modelling in New Zealand, and its models are largely based on the World Bank HDM-III and HDM-4 models[4]. All these systems are essential components of a Pavement Management System (PMS).

Bitumen Burns Card and Safety

Because bitumen burns require special treatment differing from that for burns caused by other sources of heat, the yellow Bitumen Burns Card was developed by the roading industry. It is to alert medical staff in rescue teams and hospitals to these special requirements and to communicate directly with specialist Burns Units. It is illustrated in Chapter 2, in which the importance of safety in the chipsealing industry is emphasised.

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3 dTIMS – Deighton's Total Infrastructure Management System.

4 HDM-III – Highway Design and Maintenance Standards model, version III
HDM-4 – Highway Development and Management model, version 4

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Predecessors of Transit New Zealand
Since 1989, Transit New Zealand is the RCA responsible for the national State Highway system. Its predecessors are various, and the brief family tree that follows almost needs a genealogist to interpret (see also timeline on pages 4 & 5).

The Department of Roads was established in 1901, and then amalgamated with the Public Works Department (PWD) in 1909, which had been in existence from 1870.

From 1924 the Main Highways Board (MHB) became responsible for state and main highways, serviced by the PWD. In 1954 the MHB was replaced by the National Roads Board (NRB). NRB had responsibility for state highways design, construction and maintenance, and for the distribution of most central government roading disbursements to RCAs. NRB was serviced by the Ministry of Works (MOW) which had come into existence when the Ministry of Works Act was passed in 1943. The PWD was merged with the MOW in 1948 and then ceased to exist. Following some re-organisation in the late 1970s, the MOW was succeeded by the Ministry of Works and Development (MWD).

The NRB and its Road Research Unit (RRU) continued until 1989 when the Transit New Zealand Act was passed and Transit New Zealand came into existence. Amendments to the Act were passed in 1991 and 1992, before a major amendment in 1995 created Transfund (the funder of roads) and split it from Transit (the provider of roads).

The latest change made to the family was in 2004, when Transfund and the Land Transport Safety Authority were amalgamated to form the new Land Transport New Zealand.

For a full history up to 1970, read *By Design. A brief history of the Public Works Department.* Ministry of Works, 1870-1970 (Noonan 1975).

Training
Early training was in the field, on the job and by the boss, overseer or supervisor. Generally it was minimal and learned by rote. Thus workers could become good operators but did not necessarily understand what they were doing. When problems arose the general rule was to get the boss onto them quickly. In addition technology was poor, and crews worked in high temperatures and with flammable materials, so it was a dirty hard dangerous job. High staff turnover was always a problem, meaning that training was usually not adequate to cope with these hazards. For highly trained overseers and staff however, a major source was the Ministry of Works.

Today, training programmes leading to National Qualifications within the NZ Qualifications Authority (NZQA) framework, such as NZ Certificate of Engineering, and courses at the NZ Institute of Highway Technology (NZIHT) in New Plymouth, mean more skilled staff can be trained and prepared to be career-oriented employees for the industry.

Other highly qualified people, chemists and engineers can also find niches in chipseal research. Research on the physical and chemical properties of chipseal components and the chipsealing system ensures that producing a final chipseal surface is no longer an art, but instead a controlled and consistent procedure that will deliver the desired results. This book is about the various ways that those results can be obtained.

Hanson's advocacy for scientific and rational research into roading is now a reality, and this book aims to continue building on his vision.

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