CHAPTER SIX

Chipseal Selection

Previous page: A chipseal in use on State Highway 1 just north of Kaikoura. Mt Manakau (2610 m), high point of the Seaward Kaikoura Range in the background.

Photo courtesy of Terry Hann, Wreford Hann Photography Ltd

Chapter 6 Chipseal Selection

Chapter 6 Chipseal Selection (continued)

Chapter 6 Chipseal Selection

6.1 Principles of Chipseal Selection

The success of a chipseal does not depend solely on the design of the seal. As important is the selection of the appropriate seal type for the pavement in the context of the sealing history of that pavement. Figure 6-1 shows the sequence that, in general, should be followed for selecting a typical New Zealand pavement, i.e. a flexible granular pavement constructed of layers of unbound granular aggregate, with a thin surfacing that is either a chipseal or a thin asphaltic concrete.

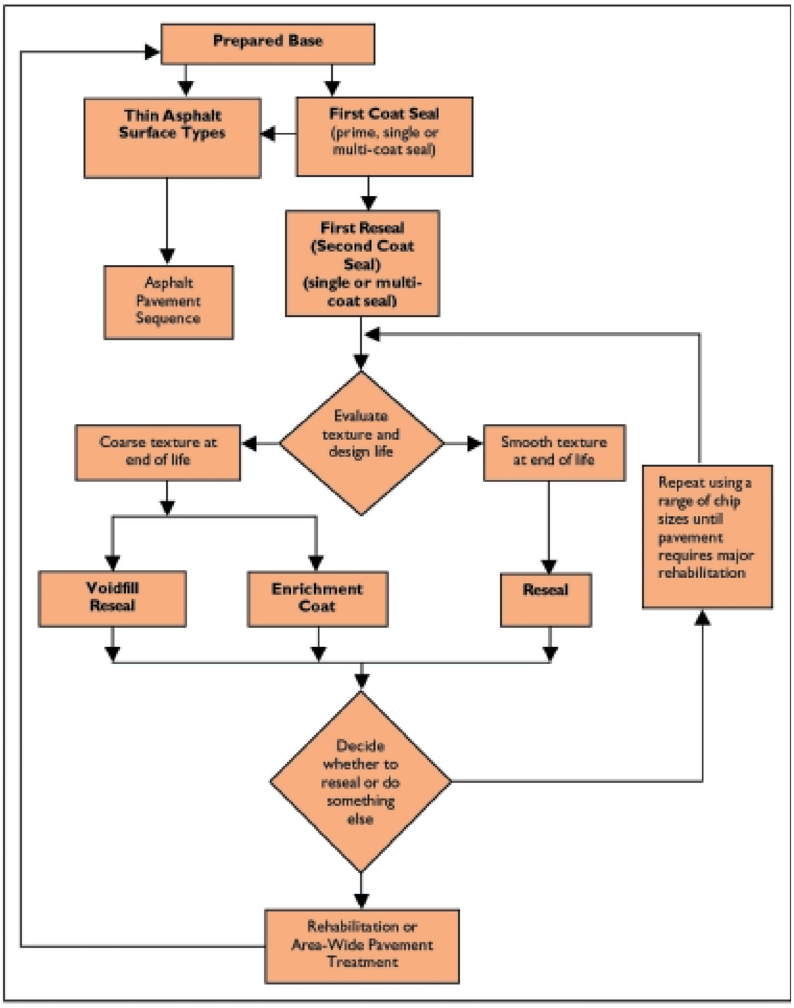

Figure 6-1 Standard sealing sequence for a typical flexible granular pavement used in New Zealand.

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The seal types introduced in Chapter 3 are presented in summary form in Table 6-1, which was developed by a representative group from Transit, Local Authorities, Consultants and Contractors. The issues considered are those arising on a straight road with low traffic volumes (e.g. 1000 AADT).

Table 6-1 Summary of seal types used in New Zealand to compensate for engineering issues arising on straight roads with low traffic volumes (e.g. 1000 AADT).

Seal Type	First Coat	Reseal	Urban/ Rural/ Residential	Risk Index High/Med/ Low	Cost Index	Life Cycle Expectations Short/Med /Long	Notes
Single coats *	Y	Y	Y – caution in Urban	H – Urban L – Rural M to H – Residential	Low	Medium	
Two coats *	Y	Y	Y	L – Rural M – Residential H – Urban	High	Long	
Racked-in seals *	Y (warning for high rainfall areas)	Y	Y	Ditto	Medium	Long	
Sandwich seals *	N	Y	Y	M	Medium	Medium	
Voidfill seals *	N	Y	Y	L	Low	Short	
Wet lock seals*	N	Y	Y	H	High	Short	Short life, as high binder to stone ratio
Dry lock seals *	Y*	Y*	Y	L	Medium	Medium	
Fog Coats / Rejuvenating / Enrichment seals *	N	Y	Y – caution for skid resistance, trafficking	M	Low	Short	
Slurry seals *	N	Y	Y	M	High	Medium	
SAM seals *	N	Y	Y	H	High	Medium	
Cape seals *	N	Y	Y	M	High	Long	Cutters and embedment issues 1st coat
Geotextile seals *	Y (over soft bases)	Y	Y	H	High	Medium	
Special skid-resistant seals *	N	N	Y	M	High	Unknown	
Asphaltic concrete *	N	N	N	N	N	N	Not used on low volume roads

* See Chapter 3 for details of seal types H – high; M – medium; L – low; N – no; Y – yes

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As defined in Section 3.3, thin asphaltic mix or thin chipseal surfacings are less than 45 mm thick over a flexible granular base, while thick rigid pavements constructed of structural asphalt are generally 110 mm or greater in thickness.

Structural asphalt and concrete pavements may require a chipseal, thin asphaltic surfacing, or some other surfacing on top to improve skid resistance and waterproofing, or to resist surface deterioration. The same general principles apply to seals on rigid pavements as to seals in flexible granular pavements, with some modifications to the seal designs as noted in Chapter 9.

6.2 First Coat Treatments

As discussed in Chapter 3, the first treatment for a granular pavement or overlay serves principally to prepare the base for the main treatment. It will normally be a first coat seal but occasionally a prime coat. The main function is to ensure a good bond between the larger aggregate in the base and the surfacing. To achieve this it is essential that any surface dust layer is penetrated or 'wet through' by a low-viscosity bitumen-based binder that can adhere firmly to the underlying stone.

> A prime coat has very low viscosity and is used to wet the aggregate, whereas a first coat seal must be considerably more viscous as it also must hold a layer of chip in place.

In many cases, a thin layer of asphaltic mix on its own is not waterproof enough to seal the pavement, especially where full compaction cannot be achieved because of a soft base or difficult laying conditions. Modification of the mix design can compensate for these difficulties and improve waterproofness. A waterproofing treatment such as a first coat seal or prime coat under the hot mix should be used with caution. The bitumen in a first coat seal will heat up when hot mix is applied to it, and then may migrate up into the thin layers of asphalt. This bitumen can saturate the mix (decreasing the % of air voids) leading to shoving and rutting (defects which are explained in Section 3.11).

Single seal coat applications on granular bases are not thick or waterproof enough to provide a durable surfacing under medium and high traffic volumes. They can fail very quickly once the first symptoms of distress appear, and if failure occurs over winter they can be extremely expensive to repair. Also such repairs will rarely be satisfactory.

Some practitioners consider two single coats will be more waterproof than applying the same amount of binder in one single coat.

After the first treatment to the base has been made, a second coat seal is applied to enhance the waterproofness of the surface. This surface will typically be durable and last for 8 to 15 years depending on the chip size and traffic volumes. At the end of this life, the next step in the surfacing life cycle will typically be a voidfill or reseal, although occasionally under very low traffic levels an enrichment coat is applied.

The cycle will continue (as discussed in Chapter 5) until the pavement requires rehabilitation because either:

- the build-up of seals has resulted in an unstable surface so that an economic life is not obtained, or
- the pavement has failed structurally.

The maintenance of even texture and prevention of flushing caused by later layer instability can be best achieved by alternating reseals of the standard with the voidfill or texturising type.

6.2.1 First Coat Seals

The first coat and second coat reseal treatments are essentially a part of the pavement construction or major rehabilitation process, and their programming is linked to the programming of the pavement works. However seals constructed in winter conditions have a much higher risk of early failure than those constructed in warmer drier periods.

Figure 6-2 A first coat seal is laid on the highway around Tauranga Harbour, Bay of Plenty. The distributor (right) is laying the binder, followed by the chip spreader (reversing over the chips newly laid on the binder). Rolling to compact the chips into the binder will follow. Photo courtesy of Philip Muir, Works Infrastructure

This risk can be mitigated to some extent by using processes and materials (such as bitumen-bound basecourse and precoated chip, etc.) specifically designed to counter the risk of early failure. Further discussion on how to prepare for a first coat seal and minimise early failures is covered in Chapter 7.

For most higher traffic volume highways, first coat seals (Figure 6-2) can be expected to survive only a single winter. In parts of New Zealand where climates are extreme, the preference may be to lay a first coat in spring as early as the basecourse can be prepared and dried out, and then to reseal it with a second coat towards the end of the construction season. Alternatively in these areas, a 'two-coat as a first-coat' seal may be a better choice.

On low volume roads, the first coat (whether a single or two coat seal) may be expected to last much longer. Construction of a second coat should be programmed based on observations of the seal surface.

6.2.2 Options for First Coat Seals

The four most commonly used treatments, in decreasing order of cost, are:

1. Seal with Grade 4 chip, followed the next year by a Grade 3 reseal.
2. Seal with Grade 3, followed the next year by a Grade 5 or 6 voidfill.
3. Seal with a two-coat Grade 3/5.
4. Seal with Grade 3.

1. ***Seal with Grade 4, followed the next year by a Grade 3 reseal***

This option has been the traditional system used on highways with high traffic levels in New Zealand. However, if the existing texture is expected to be too coarse at reseal time to meet the criteria set out in Section 9.8.5, option 2 is preferred. Where significant traffic stress levels are a problem, a two-coat seal (option 3) is better.

2. ***Seal with Grade 3, followed the next year by a Grade 5 or 6 voidfill***

For roads with medium to heavy traffic, this option is preferable to option 1 especially where experience has shown that a Grade 4 would generally give too coarse a texture after one or two years.

3. ***Seal with a two-coat Grade 3/5***

This option is considered as having an equivalent life to option 2, but provides better traffic stress resistance in the period soon after construction.

4. ***Seal with Grade 3***

This option is often used on lightly trafficked roads where failure caused by water ingress is not considered to be a high risk and where traffic stresses are few.

Options 2, 3 and 4 are not given any further seal coats until macrotexture loss or other distress indicates that they are warranted.

6.2.3 Prime Coats

A prime coat, in the road pavement context, is the application of a low viscosity cut-back bituminous material (primer) to a prepared granular base to promote a good adhesive bond between the surfacing and the base. Good adhesion of a conventional first coat seal to a granular base is normally obtained by reducing the viscosity of the binder to replicate some of a primer's characteristics. However this reduction in viscosity compromises binder cohesive strength and lengthens curing time. This is normally a problem that can be managed with careful traffic control and by timing with respect to weather and temperature conditions.

The option of a prime coat and then second coat seal is not encouraged in New Zealand or recommended for normal use because of the following three main disadvantages:

- *Safety.* Cutback primers contain a high proportion of volatile cutter which increases flammability risk during transport and application. Such a safety hazard is one of the many reasons that primers are not recommended for use in New Zealand.
- *Weather Limitations.* Damp, cold conditions inhibit the penetrating action of a primer and can dramatically increase curing times. Strong winds can cause spray drift.
- *Pollution risks.* Rain can wash uncured primer off a surface.

However, some distinct advantages are gained through the use of prime coats in certain circumstances, especially on 'greenfield' sites where the above risks are more easily controlled. A prime coat does not have to hold chip in place so it can be tailor-made to achieve the best possible bond to the basecourse surface. Its application rate is low, so some practitioners consider that a prime coat can give a superior surface for a second coat seal[1] or thin asphalt surfacing to adhere to, at a lower cost than a first coat seal.

Safety and temperature limitations, to some extent, may be overcome with the use of special proprietary emulsified primers.

6.3 Pretreatment Seals

Many pretreatments can be used to prepare a surface before resealing, as it is important to reduce any texture variation that has arisen during its life. This is called texturising and many methods of texturising are available, e.g. texturising seals, but some options do not include sealing (e.g. water blasting or other high pressure water treatments to reinstate texture: see Section 7.3.4.2).

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1 The first chipseal on top of a prime coat is called a 'second coat seal' because the prime coat itself acts as the 'first coat'.

6.4 Reseals

6.4.1 Second Coat Seals

Applying a second coat seal (reseal) over the first coat provides a thick durable layer. It is essential to give a first coat seal enough trafficking before a reseal is applied. If this is not done, the first coat may continue to compact after the second coat is laid and the result will be serious flushing. Usually second coat reseals are applied after at least six months of warm weather trafficking, in order to give the new pavement time to 'settle down' and for the seal to compact.

If a prime coat has been used, the second coat reseal should be applied as soon as practical after the prime coat has cured.

The selection of the type of second coat seal should be determined at the time of pavement design.

6.4.2 Enrichment Seals

These are a light application of binder, with no chip applied, and usually sprayed over an ageing coarse-textured chipseal, as referred to in Section 3.10.1. The binders used are usually emulsions with low bitumen contents.

They are used to:

- Rejuvenate or enrich an existing seal coat;
- Rejuvenate old very coarse seals, often in low traffic environments where the texture is still coarse, the chip is still in good condition, but the binder is becoming brittle and chip loss is beginning to occur;
- Prevent chip loss in new seals where binder has been significantly under-applied.

These rejuvenating seals are a cost-effective solution to maintaining sound coarse-textured surfacings in need of waterproofing, or more binder, or where surfacings are showing signs of failure caused by brittle binder. In the past they have been applied to chipsealed airport runways or lightly trafficked roads, but are seldom used in New Zealand on highly trafficked pavements because they create surfaces with low skid resistance.

Where appropriate, the application of a rejuvenating seal (i.e. no chip applied) can extend the life of the surfacing by maintaining the original coarse texture. If an enrichment coat is used, the skid resistance will be temporarily reduced because a very low viscosity binder is present on the upper surfaces of the larger chips. Traffic speed restrictions must remain in place until this residue is worn off and the skid resistance rises to acceptable levels.

6.4.3 Investigations for Treatment Selection

For reasons of cost and practicality, the preliminary condition survey (Section 5.1.2.4) (an input to the Forward Works and the Current Work Programmes (Section 5.1.2.5)) is not very detailed. A much more thorough investigation is required before committing to the expensive resurfacing process, and greater detail is also required to select and then to design the treatment (Section 5.1.2.6). For this reason the asset manager will prepare a list of candidate sites for sealing from the Forward Works Programme that is longer than the expected Current Work Programme. The process of detailed investigation of the candidate sections can be expected to refine the priorities in the list, and the programme is then adjusted accordingly. The detailed investigation of the condition of the pavement must also include the basic causes of any distress before any decision is made on how to treat the surface. The detailed inspection of the surface will determine if the sample measured in the condition survey really reflects the current condition.

Obviously the causes of any unacceptable pavement performance (that are not related just to the ageing of the seal) must be properly rectified before resealing, or they will simply continue to operate and will decrease the service life of the new seal as well (e.g. defects which cause flushing).

The detailed investigation and the treatment selection process must be carried out well in advance of the seal design process so that the necessary pavement and drainage repairs can be completed in enough time to allow the necessary curing and compaction of the repairs.

The final seal design process may raise further issues such as excessive texture variation or hardness variation between repair patches and the surrounding surface which may, in turn, lead to a further adjustment to the intended programme. An example is a reduction in binder application rate to compensate for a soft underlying surface.

Any significant defects should be repaired as part of the maintenance regime. Sections which are significantly improved by repairs and candidate sections which are not of high priority may be scheduled for resealing at a later time. Timing of repairs is discussed further in Chapter 7.

6.5 Seal Selection and Engineering Issues

The selection of the seal type and chip (treatment selection) is one of the most important aspects of chipsealing. In the past the choice was associated only with the size of chip to use in a single coat seal. Now a large number of seal types are available and the choice of treatment is based not solely on engineering decisions but also on cost, safety, environmental and user preferences (see Sections 6.6 to 6.10).

Figure 6-3 gives a flow chart of the basic engineering decisions that need to be made. The sealing sequence given in Figure 6-1 and the flow chart in Figure 6-3 are designed to guard against using a succession of seals having the same or similar chip size which would increase the chance of layer instability.

The flow chart is designed to be used in the following way.

1. Review the available condition data for the surface which requires resealing.

The four main conditions of the existing seal that affect the choice of treatment are:

- flushing or unstable seal, smooth-textured surfaces;
- loss of skid resistance, low macrotexture;
- cracked surfaces;
- highly stressed surfaces.

2. Start at the top left box of the flow chart (Figure 6-3), follow the arrows down and to the right.
3. Answer the questions (green boxes) which expand on the nature of the condition of the seal.
4. The flow chart will lead to the suggested treatment for the situation at hand (orange boxes).

6.5.1 Flushing or Smooth Textured Pavement Surfaces

Flushing can be the expected end-of-life condition of a seal especially under heavier traffic. If flushing as an end-of-seal-life condition has occurred, then the answer to the first question in the flow chart (Figure 6-3) would be "No". However, if premature flushing has occurred, the answer is "Yes".

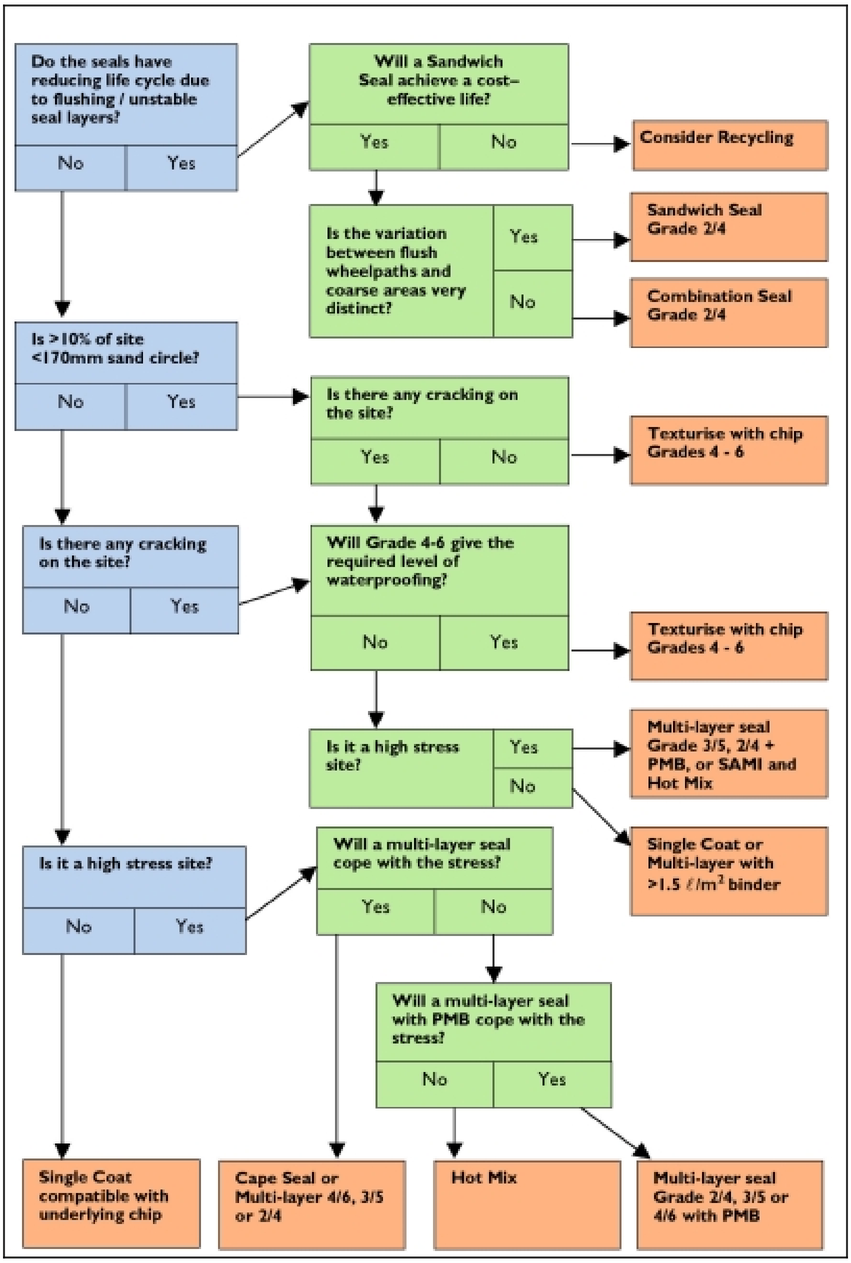

Figure 6-3 Flow chart and decision tree for deciding on a reseal.

6.5.2 Coarse Textured Pavement Surfaces

The standard New Zealand practice has been to apply a voidfill seal where the texture measured by the sand circle diameter (explained in Chapter 9) is less than 170 mm. This is to guard against obtaining a high binder:stone ratio and also to add a smaller chip to increase the chip interlock in the seal layer and shear strength of the surface.

Small chip can fit into the surface voids of a coarse-textured existing sealed surface, rather than bridging them as would a larger chip. The result is called a voidfill seal (described in Section 3.7.9). The chip chosen is usually Grade 6, although Grade 5 can be used provided that, after rolling, it does not project above the tops of the chip of the existing seal. As the binder requirement for a voidfill seal is less affected by variations in underlying texture, this seal can be applied over a variable coarse surface to reduce the variation in macrotexture. The texture of this new surface is quite independent of the original surface. If used appropriately, voidfill seals can prevent cumulative development of uneven texture.

Since the surface voids of the underlying existing chipseal are largely filled with chip instead of binder, the 'mix' of layered seals will have a lower binder content and be far more stable. Thus the chance of embedment of subsequent seals is greatly reduced. However voidfill seals must not be applied to flushed or bleeding wheelpaths as this will tend to exacerbate the problem.

Where the binder has become brittle and the risk of chip loss is likely, the existing chip usually stands well proud of the binder. A voidfill is an ideal treatment in this situation. Frequently voidfills need to be applied in adverse winter weather conditions under considerable traffic. In such conditions, a Grade 6 chip with an emulsion binder is usually the most suitable combination. (Bituminous emulsion can have superior adhesion qualities in damp and cold conditions, but it must be tailor-made to provide a fast enough break-time.)

A Grade 6 voidfill coat is often resealed within 2 years if the traffic density is high, because the macrotexture of the reseal has reduced to the extent that flushing is imminent.

Much better service life can be achieved if the voidfill is applied to coarse areas one to two years before the condition of the old seal demands a reseal. Used in that way the voidfill chip can interlock well with the remaining texture, and the voidfill seal is not required to bridge extensive cracking. Such early intervention can enable a larger chip to be used, such as Grade 5 or even 4. In this case a good waterproof surface can be maintained for 4 to 5 years, giving a much more economical result. For best results, the size of voidfill chip should be determined to find the largest chip size that will properly interlock with the original texture and yet not increase the texture depth.

6.5.3 Cracked Pavement Surfaces

As discussed in Chapter 4, cracking is one of the main end-of-life conditions for a chipseal. Once a chipseal is cracked, water can enter the lower layers of a pavement and cause damage. Cracking is generally repaired by resealing, though chipseals using polymer modified binders (PMBs) called SAMs (Stress Absorbing Membranes) are also used, and crack filling is another option. More information is given in Chapter 7 and Section 8.4.

(a) Crack Filling

Where pavement cracking is not extensive, crack filling or bandaging can be used to repair it, as described in Section 7.3.3.1.

(b) SAM or SAMI (Stress Absorbing Membrane Interlayer) Seals

Where pavement cracking has become so extensive that crack filling is not an economic option, or the cracks are narrow but extensive and cannot be filled with a normal chipseal with a higher bitumen application rate, the use of a PMB (e.g. in a SAM, or SAMI) or a geotextile seal can be an economic alternative to reconstruction. Filling the wider cracks before the membrane is applied is recommended.

(c) Chipsealing

Where cracking is hairline (<1 mm wide) and affects less than 5% of the pavement, the repair is simply a normal reseal using chipseal with a chip size that gives a binder application rate of greater than 1.5 ℓ/m^2.

6.5.4 Stressed Pavement Surfaces

Pavement surfaces fail on corners, intersections and steep gradients where the high stresses are caused by braking or turning traffic. If severe enough, traffic stresses can tear out chips from the chipseal surface and the surface then rapidly loses its integrity.

These high stress sites can be divided into those that are associated with:

- Cornering;
- Braking and slow-speed turning.

In practice the seal designer would inspect the site in order to assess the stress levels (always assuming a sound substrate), and could increase or decrease the classifications for cornering, braking and turning based on site-specific conditions.

6.5.4.1 Cornering

High stress corners can be rated 1 to 6 according to the advisory speed, supplemented by the gradient, as proposed in the following classification (Table 6-2).

Table 6-2 Classification for stress rating on corners.

Gradient (%)	Advisory Speed (km/h)			
	<30	30-50	50-70	>70
<5	4	3	2	1
5-10	5	4	3	2
>10	6	5	4	3

In this classification, the lower the number, the lower the stress on the site, so that a classification of 1 implies that the stress is very low and the section is flat and relatively straight.

The number of heavy commercial vehicles (HCVs) would affect the ranking because HCVs with multiple axle groupings or spaced axle trailers can cause additional shear forces (often called 'tyre scrub') by the non-steering wheels being partially dragged around turns. This effect is exacerbated where speeds are low.

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6.5.4.2 Braking and Turning

Braking and turning areas which may require specialised treatment include:

- Roundabouts;
- Intersections;
- Commercial driveways (in industrial areas);
- Railway crossings;
- Pedestrian crossings.

Using the same rating system of 1 to 6 as for cornering, but based on traffic volume per lane per day (HCV/l/day), the following classification (Table 6-3) is proposed.

Table 6-3 Classification for stress rating for braking and turning areas.

Number HCV/l/day	Roundabout	Intersection	Commercial Driveway	Railway Crossing	Pedestrian Crossing
<20	5	3	5	2	2
20-50	6	5	6	3	4
>50	6	6	6	4	4

Again the comments regarding tyre scrub generated by HCVs apply here, and in all cases, the rating should be adjusted accordingly to account for this.

6.5.4.3 Ranking of Seal Strength for Stressed Sites

Table 6-4 shows an approximate ranking of the resistance of the different seal types against the shear stresses of turning and braking traffic.

The use of polymers in the binder will usually not affect the stability of the chipseal as much as a change in seal type, and will usually cost a little more than the next most expensive option in the list in Table 6-4. Other options to improve the stability of the chipseal, such as the use of less cutter or more stiff binders, along with precoated or heated chips, and active traffic control, are effective and may be more economical.

Table 6-4 Approximate ranking of seal types according to their surfacing strengths.

Strength	Seal Type		Price
	Single Chipseal		
	Dry Lock		
Increasing Shear	Racked-in Seal		
Strength	Two Coat Seal	Slurry Seal	Increasing Price
	Cape Seal	Polymer Slurry Seal	
	Dense Asphalt	Open Graded Porous Asphalt	

The ranking shown in Table 6-4 is not hard and fast because performance depends critically on design, construction, and the weather during and after construction. For example, a single coat chipseal that has been well designed and constructed, and laid in the most favourable season, may outperform a poorly constructed dense graded asphalt. This makes it difficult to set absolute rules about when to use the different types of seal.

When considering the sealing of high stress parts of a road, the relative economy of changing seal types versus carrying out the operation in the most favourable part of the sealing season should be carefully considered. This simpler remedy may be all that is needed. Additional traffic control to direct slowly moving vehicles over the fresh seal, and to move the traffic stream gradually across the entire width of the seal to aid compaction, is usually very cost-effective. However the costs of traffic delays must be considered.

Within each seal type, smaller chip tends to be less adversely affected by traffic shear forces than larger chip. This is more pronounced for single than for multicoat seals.

In addition, the nature of traffic stresses has a very strong influence, so that single coat chipseals may perform very well on very steep grades and tight curves if traffic is low to moderate. However under heavier traffic and higher stresses, a single coat chipseal generally cannot be expected to perform.

6.5.5 Layer Instability

6.5.5.1 Introduction

Analysis of the failure mode of a surfacing for which layer instability (described in Section 4.7.4.2) is suspected, is best described by introducing the concept of binder:stone ratio (Gray & Hart 2003).

However, awareness is currently limited to a pragmatic understanding of the limits of the binder:stone ratio in the layer which is most susceptible to layer instability.

Current best practice suggests that, when the cumulative chipseal layer depth exceeds 40 mm and the binder:stone ratio approaches 12% by weight of binder, sealing practitioners should be alerted to the possible presence of layer instability.

They should approach the seal design process for that particular pavement section with caution. For incremental steps above the 12% trigger, different treatment options should be used, each of which are focused on lowering the binder:stone ratio.

The suggested 12% trigger value does not equate precisely to the point at which concern over the stability of an asphaltic mix would arise. However, the chip properties (e.g. grading) that are present in multiple chipseal layers differ somewhat to those that would be present in an asphaltic concrete mix design (Asphalt Institute 1997).

The 12% trigger has been derived through analysis of pavements where flushing is present and layer instability was found to be a contributing factor. This empirical trigger was based on extensive analysis of flushed pavements in the Hawke's Bay area between 1995 and 2003 (Gray & Hart 2003). These factors and triggers may however be different in different climatic conditions.

6.5.5.2 *Identification of Failure Mode*

A generic model has been developed to assist with the identification of candidate treatment lengths for technical analysis with regard to possible layer instability, against the above criteria (see box in Section 6.5.5.1). This model poses the following questions for a candidate length:

- Is flushing a failure mode?
- Is loss of texture rapid and/or premature?
- Was flushing evident before the previous resurfacing?
- Was the life of previously applied reseals getting shorter, and reducing after each successive treatment (referred to as a 'pinching reseal cycle': as in Figure 5-5)?

If affirmative answers to the above questions predominate, consideration should be given to taking a core sample of the layer for technical analysis. This core is analysed against the layer depth and binder:stone ratio criteria. A core will also allow the underlying layer material types and thicknesses to be established.

6.5.5.3 *Treatment Options*

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Options suggested for the treatment of surfacings where layer instability is identified as a failure mechanism are focused on modifying the binder:stone ratio of the layer. Unless this is effectively corrected, normal performance cannot be expected from any conventional reseal applied to the flushed surface.

Obviously different treatment options will influence the binder:stone ratio to different extents. Although not proposed as the definitive and complete list of treatment options, the following typical treatments give an indication of the degree of correction that can be expected and the suggested application of these.

Where the layer depth is greater than 40 mm, and the measured binder:stone ratio is:

- *Around 12% or less by weight*

  The risk of layer instability becoming a problem is low. If flushing is present, conventional treatments designed to remove surplus bitumen should be considered in favour of covering the excess binder with further reseals. Otherwise, if buried by a new chipseal, the excess binder will contribute to future layer instability. Water blasting or other high pressure water treatment is a common suitable treatment.

- *Between 12% and 15% by weight*

  The risk of layer instability resulting in premature failure of a subsequent reseal is a possibility. At this level, treatments designed to reduce the binder:stone ratio become necessary, e.g. water blasting or other high pressure water treatment (to reduce the binder content), or hot chip (to increase the chip content). Generally, applying cutters to enhance the take of fresh chip is not desirable because the diluents may permanently affect the viscosity of the binder near the surface and accelerate deterioration of the layer.

- *Between 15% and 20% by weight*

The risk of failure is high, and any treatments must target a significant correction. The sandwich seal treatment was designed for application in such areas. A layer of Grade 2 chip is applied dry to the existing surface, followed by a low application of bitumen to retain a Grade 4 wet lock seal. Applications of bitumen between the Grades 2 and 4 layers at rates as low as 0.8–1.0 ℓ/m² are being achieved.

This surfacing treatment is proving very durable, is being applied in high demand locations with good success, and obviously provides a significant correction to the binder:stone ratio (i.e. much new chip, very little bitumen). Further, the layer has significant potential to absorb any fresh free bitumen rising to the surface before flushing becomes an issue again. In an urban environment a Grade 3/5 sandwich seal may be a more appropriate solution from an environmental or social perspective.

- *Above 20% by weight*

Experience is proving that an entire layer with more than 20% by weight binder:stone ratio needs treatment. Options include a granular overlay, pavement rehabilitation or recycling.

Recycling was developed as a technique designed to mix the existing surfacing layers with the underlying basecourse plus additional material, e.g. extra aggregate and a small amount of cement (between 2% to 3%) before applying a fresh first coat surfacing. This is essentially converting the existing pavement, including unstable multiple chipseal layers, into a bitumen-stabilised basecourse.

If undertaking conventional reconstruction or overlay however, care should be taken when burying the existing layer with only a thin depth of overlay material, as the structurally unstable layer may continue to deform and shear under the shallow overlay depth. Further information on the recycling process is found in the paper by Gray & Hart (2003).

6.5.5.4 Analytical Representation

These site identification techniques and treatment options are summarised in the decision-making flow chart of Figure 6-4.

6.5.6 Exception Reporting

Exception Reports, as the name suggests and introduced in Section 5.2.1, report the assets which are performing below the required level of service and are therefore 'exceptions' to an otherwise compliant network. Exception reports greatly assist in identifying pavement sections that are performing poorly but have not yet fallen below the required level of service. These sections can then be programmed for treatment just before the level of service falls below the prescribed level. Their usefulness in relation to layer instability is discussed here.

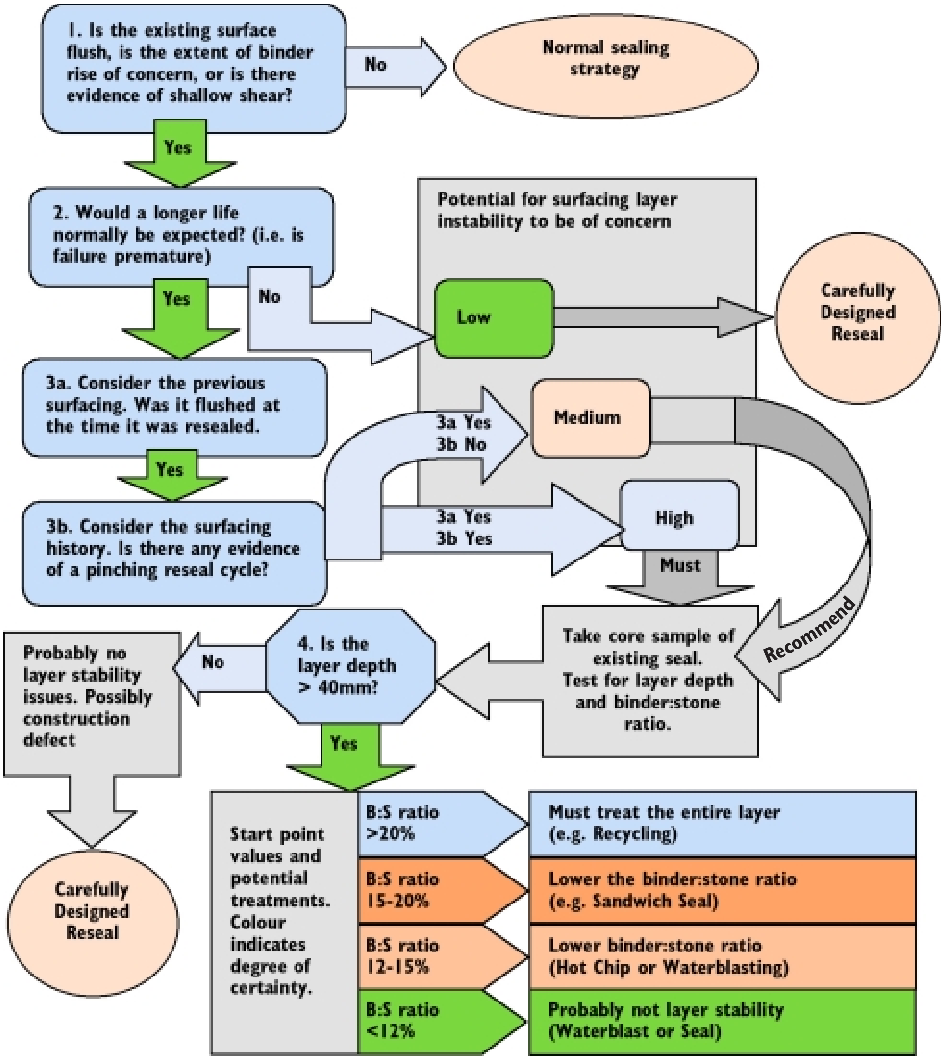

Figure 6-4 Decision-making flow chart for treatment selection analysis.

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Reasonable success with the identification of potential layer instability sites has been achieved using exception reporting from the RAMM database. For example, the RAMM database contains the following information at a treatment length level:

- Presence of flushing: easily interpreted from condition data.
- Premature failure: RAMM can report on the expected seal life at a generic level (Table 4-4 lists the default seal lives). RAMM also contains data for each reseal where the 'expected life' field has been updated.
- Reduction in texture depth: when texture depth reduces by 0.3 mm per year or more between annual high speed data surveys.
- Shortening (pinching) reseal cycle: treatment lengths are flagged by RAMM where the life of each successive reseal is reducing.
- Flushing before the last reseal: interpreted from historical surfacing and condition data.

6.6 Seal Selection and Road User Safety

The safety of the road user is an important consideration when selecting the appropriate chipseal or treatment. Skid resistance and the complementary topic of texture depth is crucial to a safe surface and is dealt with in some detail below and in Section 4.9. How skid resistance is affected by frost and ice is considered in Section 6.8. Other road user safety factors are touched on in this Section 6.6, particularly water spray and roadmarking contrast.

6.6.1 Skid Resistance

6.6.1.1 Relationship Between Skid Resistance and Crashes

As discussed in Section 4.9, raising the skid resistance of the road surface decreases the rate of wet skidding crashes. Also different sites present different risks (as explained in Section 4.9.2).

> If skid resistance is below the Investigatory Level (Table 4-5) as defined in TNZ T/10, or any other safety-related defect is observed, some type of remedial treatment must be applied promptly.

Road surfaces requiring high levels of skid resistance are normally associated with high levels of traffic stress. The PSV of the chip and the minimum texture depths need to be considered, and that means some surfaces cannot be used for the open road, e.g. Type 3 slurries (as they are not coarse textured enough for high traffic volume roads).

In deciding on the treatment that should be used, available sources of chip having high PSV need to be considered. Under high traffic loading, normal sealing chip may polish very quickly, and then special treatments using artificial chip (e.g. calcined bauxite) need to be used. These treatments are at least ten times more expensive than a normal chipseal but are becoming more common in New Zealand to achieve the safety benefits of adequate skid resistance.

Where failed surfacings or high stress situations occur, a chip with a proven on-road performance in similarly stressed situations should be used.

6.6.1.2 Treatment Selection for Skid Resistance

Site Assessment

For the state highway network an Exception Report (see Sections 5.2.1 and 6.5.6) is compiled to record all sites that have a skid resistance of >0.1 SFC (Sideway Friction Coefficient) below the Investigatory Level (IL). These sites are assessed to programme them for treatment and, as is always important in treatment selection, the assessment includes a site investigation as well as an inspection of the survey results to make a treatment selection decision.

If the investigation shows no reason to doubt the survey results and the site is below the Investigatory Level, then a treatment to improve the skid resistance should be considered. If the maintenance treatment cannot be applied because of weather restrictions (e.g. too late in the sealing season), then temporary signs (e.g. 'slippery when wet') to warn the motorist may be appropriate.

If, after investigating the site and reviewing all the site data, some uncertainty exists with the result of the survey data, the results need to be confirmed (by re-testing). Often a SCRIM machine is not available for this type of work, and in this situation other available skid testers could be considered, e.g. British Pendulum Tester (BPT), GripTester, Norsemeter RoAR (see Figure 4-22).

Although the correlation between these machines and the SCRIM is not ideal, testing may be undertaken in the area under investigation and in an adjacent area that complies with the Investigatory Levels, as a comparative test (Figure 6-5).

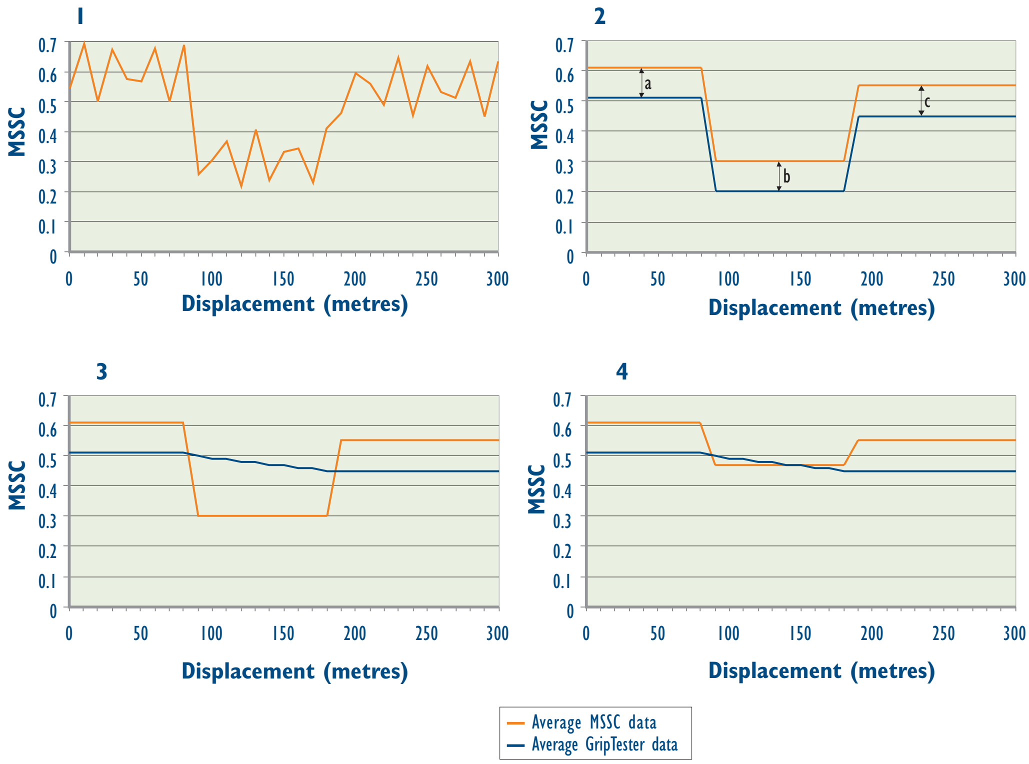

Figure 6-5 Comparative tests using a different skid tester where some uncertainty exists in the SCRIM data.

1. A non-complying section of SCRIM data between 100 to 180 m displacement of chipseal along the road.
2. A test run with the GripTester. If a ≈ b ≈ c, then non-complying section is a permanent condition and SCRIM is correct. Take action to fix defect.
3. This test run shows that the non-complying section is a temporary situation, and no action is needed.
4. If only the non-complying section had been tested, it would have been impossible to tell if the condition was temporary or permanent.

If the results from the additional skid tests indicate that the skid resistance of the surface is likely to be below the Investigatory Level, the data should be included with other factors in producing the Current Work Programme for resealing. This produces a proactive skid policy and not simply a reaction to skid-related crashes. This proactive strategy, and the alternative, a reactive skid resistance strategy, are outlined in the Austroads *Guidelines for the management of road surface skid resistance* (2005).

If the investigation confirms that the site is below the Investigatory Level and there is sufficient texture depth, the surfacing aggregate on the existing pavement should be evaluated to determine if the low SCRIM value is to be expected or not.

To assess if the aggregate's skid resistance properties are performing on the road as they should, use the PSV equation from TNZ T/10:

$$\mathbf{PSV = 100 \times SFC + Q \times 0.00663 + 2.6} \qquad \text{Equation 6-1}$$

where:

SFC is the ESC (Equilibrium SCRIM Coefficient, as per TNZ T/10) (see Table 4-5) required;

Q is the commercial vehicles per lane per day (> 3.5 tonne).

This equation can be re-arranged to:

$$\mathbf{SFC = \frac{(PSV - (Q \times 0.00663 + 2.6))}{100}} \qquad \text{Equation 6-2}$$

Thus by putting the PSV of the chip that is in service on the road and the commercial vehicles in the equation, the calculated SFC can be obtained and compared with the measured SFC.

If there is no significant difference between the calculated value for SFC from Equation 6-2 and the survey results, the results can be considered 'expected'.

If the difference is significant between the calculated and measured SFC value, then the result would be considered 'unexpected'.

It is important that, when selecting a chip for the resurfacing, it has the required PSV. Although the PSV test is probably the best method available to illustrate how a chip will polish in service, a number of variables such as weathering, size of chip, angularity, traffic stress, etc., are not taken into account in the PSV Equation 6-1. Thus the relationship between PSV and SFC in Equation 6-1 should be regarded as merely indicative.

Where skid resistance problems have been experienced, and this necessitates a new surfacing, the materials chosen should have a proven on-road skid performance in similarly stressed situations.

In cases where the PSV equation indicated that the chip should have given the appropriate SFC, yet has fallen short, there could be additional stresses acting on the site.

Using the constant in the PSV equation as a stress factor can compensate for these additional stresses.

Hence the PSV equation can be displayed as:

$$\textbf{PSV} = 100 \times \textbf{SFC} + \textbf{Q} \times 0.00663 + \textbf{stress factor} \qquad \text{Equation 6-3}$$

Stress factors not accounted for in the equation include:

- gradient,
- curvature relative to travel speed, e.g. 80 km/h design curves on open roads,
- braking zones, e.g. approaches to intersections,
- on and off ramps,
- acceleration zones,
- intersections, turning areas, roundabouts.

Some research has indicated that the PSV equation is not as accurate as was once believed. However, it is still the best estimate available but should be used with caution.

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6.6.1.3 Example Calculation Using the Stress Factor

Site Details:

Commercial vehicles:	=	200 per lane per day
PSV from test:	=	50
SCRIM survey result:	=	0.42
Site Category:	=	2 (from Table 4-5)

Steps:

1. Using the re-arranged equation, calculate if survey result is expected:

$$\textbf{SFC} = \frac{(\textbf{PSV} - (\textbf{Q} \times 0.00663 + 2.6))}{100}$$

$$\textbf{SFC} = \frac{(50 - (200 \times 0.00663 + 2.6))}{100}$$

$$\textbf{SFC} = 0.46$$

Thus the survey result is unexpected since the survey result is 0.42 and the calculated result is 0.46.

Even if the chip performed as the PSV dictated, the SFC value is still too low since the SFC requirement for a category 2 site is 0.5.

2. Determine the in-situ PSV for the chip by using the SCRIM survey result as the SFC in the equation:

$$\mathbf{PSV = 100 \times SFC + Q \times 0.00663 + 2.6}$$

$$\mathbf{PSV = 100 \times 0.42 + Q \times 0.00663 + 2.6}$$

$$\mathbf{PSV = 46}$$

Even though the chip has a measured PSV of 50, it is only providing skid resistance equivalent to that of a chip with PSV = 46 due to the stress at the location.

3. Determine the stress factor by calculating the difference between **actual PSV** and **in-situ PSV**:

Stress factor = (50 – 46) + 2.6
Stress factor = 6.6

4. Use the stress factor in the PSV equation to determine the required PSV at this particular site:

For Site Category 2, the required ESC is 0.5 (Table 4-5).

Therefore the PSV required is:

$$\mathbf{PSV = 100 \times 0.5 + 200 \times 0.00663 + 6.6}$$

$$\mathbf{= 58}$$

Therefore the PSV required:

- to take into account the additional stress at the location and
- to provide an SFC of 0.5
  is **58**

6.6.2 Water Spray

Another aspect to consider in addition to skid resistance, when selecting seals to improve road safety, is water spray. Water spray needs to be minimised so that drivers can see where they are going when following taller heavy vehicles (trucks) which can generate heavy sprays of water in wet weather.

The amount of water spray is directly related to road camber and the quantity of water, and inversely related to texture depth and porosity of the surface, i.e. greater texture depth will reduce water spray, as will greater porosity.

Although the minimum texture depths required for skid resistance also assist in minimising spray from heavy vehicles, a higher degree of spray suppression can be required on some lengths of road. These may be areas where heavy vehicles are passed and clear visibility is required, as for example on passing lanes and divided carriageways (Figure 6-6). An increase in the texture depth (more than the minimum required) through the use of a large chip or alternatively the use of OGPA (open-graded porous asphalt) should be considered.

Figure 6-6 A chipseal on climbing lanes where high speed traffic passes heavy vehicles.

Photo courtesy of Allen Browne, Opus

6.6.3 Roadmarking Contrast

Another aspect of road safety is delineation. Delineation is achieved through roadmarking, edgemarker posts, reflectorised raised pavement markers (RRPMs), and other visual cues, e.g. chevron boards, guardrails, and sight rails.

Visibility of road markings on wet nights can be a problem on pavements with low texture depth, especially on dense graded asphaltic concrete. In deciding on a surfacing treatment this problem needs to be considered, especially in urban areas.

Although a Road Controlling Authority (RCA) may have a policy that allows a lower texture depth than specified in TNZ T/10, the safety aspects of wet-night visibility need to be considered. Safety aspects can weight the decision towards high-texture surfacing treatments in urban areas and in other areas where high traffic volume means delineation in wet-night conditions is important.

Alternatively, specialised delineation treatments can be applied to areas of dense graded asphaltic concrete to ensure wet-night visibility. Options include specially textured thermoplastic markings, or thicker applications of roadmarking paint that incorporate larger sized glass beads. Information is available from the NZ Roadmarkers Federation on the selection of roadmarkings (NZRF 2004) and from their website: www.nzrf.co.nz/docs/MaterialsGuide0404.pdf

6.7 Seal Selection for Bridge Decks

A bridge is a structure specially designed to cross a gap in the road network, usually over drainage systems. The bridge decks have to withstand high stresses, and are generally constructed of rigid materials which means they require special consideration when selecting the appropriate treatment for sealing them. For more information see Bridge Inspection and Maintenance Manual (Transit NZ 2001).

Because of their special design requirements the regional bridge engineer should always be consulted for advice and input by the surfacings engineer in charge of maintaining and re-sealing the roads in that region.

The construction and materials of the bridge deck determine the kinds of surfacings and treatments that can be applied to it. For example, some culverts for drainage systems (Figure 6-7) form part of the roadway, and the pavement runs straight across them, e.g.

Figure 6-7 An example of a culvert with a high fill. In this case, design of the pavement and surfacing are as for a conventional subgrade (see Section 3.3).

Photo courtesy of Frank McGuire, Transit NZ over corrugated steel culverts and concrete box culverts. In these cases the surface treatment and its design and construction are the same as for the conventional pavement over the rest of the road. In cases where the fill over the culvert is shallow (e.g. < 1.5m) specific design is required for the pavement.

The structural capacity of the bridge is designed to sustain specific loads including the weight of the surfacing to be used. So although a thin surfacing applied to the constructed bridge deck is allowed for in the bridge design, there is a limit to the thickness and number of layers that can be added during successive maintenance treatments. Therefore before changing the surfacing of a bridge, and possibly adversely altering the loading on the bridge structure, the road surfacing engineer should consult the bridge engineer for advice.

6.7.1 Functions of Bridge Deck Surfacings

The functions of the bridge deck surfacing are to:

- accommodate and smooth out deck surface irregularities arising from construction;
- produce a trafficable surface;
- facilitate a smooth ride;
- provide a safe skid-resistant texture;
- maintain colour continuity and texture that are consistent with the approach road;
- facilitate efficient drainage of rainwater from the carriageway by co-ordinating the surfacing with kerb-side drainage channels, drain holes and scuppers;
- waterproof the deck structure;
- promote durability of the deck structure by providing additional protection to reinforcement steel for concrete decks and to steel-plated decking (this is particularly desirable if de-icing salts are likely to be used during the life of the bridge);
- provide a safe, uniform texture and aesthetic consistency with the approach road (Figure 6-8).

6.7.2 Maintenance of Bridge Decks

While the rationale for maintenance for many of the various surface treatments which apply to road pavements can also apply to bridge deck surfacings, special conditions do arise. Several types of surfacing defects are typically only associated with bridge decks, and include:

- delamination of the wearing surface from the deck substrate;
- erosion at deck joints;
- differential settlement and surface discontinuities at abutments (see Figure 6-10).

Figure 6-8 An approach road that is consistent with the bridge deck surfacing.
Photo courtesy of Frank McGuire, Transit NZ

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Rectification of these defects requires specific treatments that are not usually provided in routine surfacing operations for roads. As a consequence the bridge engineer must be consulted for their design input before specifying and undertaking a maintenance treatment for a bridge deck.

Another example is a bridge surface that requires scarifying before resurfacing, when care is required to:

- ensure that scarification does not go deeper than the surfacing;
- avoid eroding the permanent part of the deck;
- avoid interfering with the steel reinforcement; and
- avoid reducing both the concrete cover and the structural load-bearing capacity of the bridge.

6.7.3 Selection of Surfacings

The service life of a bridge surfacing is likely to be longer as the substrate is uniform and stiff compared to the flexible surfacing for the approaches. The end-of-life for the bridge surfacing is usually dictated by either embrittlement of binder or cracking.

Normally the approaches can be chipsealed and matched to the surfacing used on the bridge, but a reseal of the adjacent road does not necessarily mean the bridge should also be resealed at the same time.

Multiple seals can result in excessive surfacing thickness at transverse features, e.g. joints, and must be applied carefully so they are kept at fixed elevations.

Other deck types, such as orthotropic steel plate deck, give rise to problems in developing adequate adhesion between the steel substrate and the surfacing interface, to the extent that chipseals are not an appropriate surfacing. These deck surfaces (e.g. steel deck in an orthotropic plate span) do not have enough surface texture for chipseals to lock on to and they may delaminate. For these surfaces special bridge overlays are employed.

Selecting chip size and bitumen application rates are as for a conventional chipseal and other relevant guidance appropriate for a bridge deck surfacing is covered in Section 9.8.6.

6.7.4 Surfacing Types for Bridge Decks

The focus of this book is primarily on thin bituminous chipseal surfacings, although these are only one of many types of surfaces and materials that may be employed on bridge decks.

The application of a chipseal over a bridge deck can be an effective and warranted treatment, provided that the function of the deck joints is not impaired by the intrusion of bitumen and chip, that the new surface does not compromise the structural capacity of the bridge deck to sustain traffic loads, and the bridge engineer is in agreement.

In New Zealand, bridge decks whether of concrete, steel, wood, or other materials, are usually surfaced with a range of generic surfacing materials for bridges including:

- Thin bituminous surfacing (as in a chipseal);
- Asphalt mix of thickness capable of restoring a smooth ride and a safe trafficable surface;
- Special materials, e.g. epoxy, polyurethane, bitumens modified by additives to promote adhesion at the deck–surface interface, materials resistant to solvents and chemical spills;
- Surfacings of special details, e.g. asphalt plug joints;
- Materials that promote skid resistance of the wearing surface, e.g. calcined bauxite chip;
- Geotextile seals (Figures 6-9 and 3-26) to restrict water from entering bridge joints.

The use of special treatments and materials is dictated by serviceability requirements of deck joints, differential movements at joints between original and widened parts of bridges, and by the need to provide adequate confinement at the edges of surfacings. Bruce et al. (1999) identified deck joints as the most common maintenance problem on concrete bridges. Such defects should be treated before applying a conventional surface treatment.

In special cases the surfacing is required to act integrally with the bridge deck to provide composite action and to enhance the load-bearing capacity of the bridge (e.g. the Auckland Harbour Bridge extension spans with asphaltic concrete surfacing). In these cases the addition of a simple overlay may not be appropriate.

Figure 6-9 A geotextile two coat seal being applied to a single-lane timber bridge (on State Highway 6, West Coast of South Island) to protect joints and metal parts from the effects of water.
Clockwise from top left: Laying the geotextile over hand-sprayed tack coat. Top right: Smoothing down the geotextile. Middle right: Spraying the geotextile with the binder. Bottom right: Spreading the chip over the geotextile. Bottom left: Rolling the chip onto the geotextile. Middle left: Spraying the second application of binder over the geotextile and first chip layer. The next step is to apply a second layer of chip.
Photos courtesy of Les McKenzie, Opus

6.7.5 Approach Abutment Pavement Surfacings

A key consideration at many bridge approaches is the maintenance of a smooth ride at the transition between the abutment pavement and the bridge deck surface.

Figure 6-10 Differential settlement of the earthfill at the abutment (from Transit NZ 2001).

Differential settlement of the earthfill at the abutment (e.g. settlement of slabs) relative to the deck surface is difficult to avoid even with careful design, construction and compaction of the earthworks (Figure 6-10). Therefore the bridge engineer should be consulted as the settlement may be an indicator of other structural issues requiring specific treatment.

Correcting uneven approach surfaces with basecourse hard fill and/or an asphaltic mix can best be done at the time of a surface treatment. Care is required to produce a smooth transition from the approach road across the bridge deck that is of sufficient length to ensure a smooth ride and reduce vehicle bounce.

Road users benefit from a smooth ride and there is benefit to the bridge as well, as a smooth approach reduces the dynamic loads imposed by bouncing vehicles.

6.7.6 Some Helpful Pointers to Preparing a Bridge Deck for Surfacing

- Check the deck surface for signs of structural deterioration.
- Discuss maintenance treatment options with the bridge engineer to ensure that the chosen maintenance treatment for the surfacing is appropriate.
- Check if:
  - (a) Smoothing treatment on the approaches is likely in the near future. If so, it may be appropriate to defer the deck and adjacent road reseal until approaches have been prepared.
  - (b) Maintenance and repairs to deck joints are required before chipsealing.
  - (c) Intended chip size (and any associated pretreatment) will result in unacceptable superimposed deck loads.
- Cover or mask bridge deck joints to exclude bitumen and chip from the joint before applying the chipseal or other bituminous surfacing, and clear them after the sealing has been done.
- Locate deck drains and scuppers before applying the chipseal or other bituminous surfacing, and ensure they are not blocked after the treatment.
- Check the deck surface for signs of any deterioration of the structural capacity of the deck. Cracking of a concrete bridge deck may require treatment and/or special membrane treatment to prevent water penetration or corrosion of reinforcing steel.
- Complete any necessary structural repairs to the deck surface and joints before applying bituminous surfacing.
- Timber decks can impose special requirements for a suitable flexible surfacing. They usually need a primer treatment to promote and ensure adhesion of the chipseal surfacing to the timber substrate.
- If the detail of the job is not simple, check with a bridge specialist.

6.8 Seal Selection for Frost, Ice and Snow Conditions

6.8.1 Introduction

Frost, ice and snow present a particular hazard to road users (Figure 6-11) because they dramatically reduce the skid resistance of the road surface. Of the three, frost and ice are the most hazardous as they are unexpected, because their presence is not obvious. Frost and ice can occur on short sections of New Zealand roads in winter conditions, except on roads in Northland and on most coastal highways.

Figure 6-11 Keeping traffic flowing along snow-bound and icy roads requires special chipsealing applications. Photo courtesy of Les McKenzie, Opus

Many influences affect the formation of ice on roads. Some are regional such as:

- location and
- climate.

However, many of these influences are highly location-specific such as:

- shading which influences radiation gain or loss;
- road surface type;
- nature of the basecourse and subgrades;
- depth to water table and moisture content of pavement layers;
- road gradient.

6.8.2 Formation of Frost and Thin Ice on Roads

Frost and ice formation occur on road surfaces that are about 0°C or less, but the reasons that the road cools down to this temperature are much more complex. The thermal properties of the road surface and base layers influence its heat-storage and heat-flow capacity (VTI 1981), while the terrain and adjacent trees influence how much sun reaches the road in the daytime. Usually the sun heats the road more than the adjacent land during daytime and, as the road has better heat-storage and heat-flow properties than the adjacent land, it cools more slowly at night (for most situations).

Frost or ice is less likely to form on a road exposed to sun compared to the adjacent land. Conversely, areas shaded from the sun all day will have no reservoir of heat and will be prone to frost or ice formation.

The important role of the base layers as a heat reservoir means the road surface has a lesser effect in reducing frost and ice formation. Dense dark-coloured asphalt surfaces are much hotter than chipseal in direct sunlight, but this difference is of little relevance in New Zealand outside the alpine regions.

The main categories of winter condition on the road identified in the Swedish research (VTI 1981) are:

- Hoar Frost (white frost);
- Ice: thick ice (several layers of ice crystals thick); thin ice or ice glaze (one layer of ice crystals); ground icing;
- Snow: loose snow, compacted snow, slush, sleet.

Hoar frost (white frost) forms when the temperature of the road is both less than 0°C and less than the dew point of the air immediately above. (The dew point is the temperature where the water-holding capacity of the air is at its limit, i.e. its relative humidity is 100%.)

Frost can form in three main types of weather, all of which are relevant to New Zealand but the first two are the most common.

– clear calm nights when radiative cooling rapidly cools the road but the air temperature is close to 0°C;

– after a cold clear night when the rising sun causes air circulation, and moist air moves above the already cold road;

– after a cold but cloudy night, the sky clears and the road rapidly cools but the air is still moist.

Thin ice or 'ice glaze' is one-crystal layer-thick ice that moulds over the macrotexture of the road. This condition is considered to result from:

– super-cooled rain landing on a road surface that is close to 0°C, where it instantly freezes;
– light rain on a road surface which is already less than 0°C, where it quickly freezes;
– moisture on a cooling road from earlier dew or light rain, which then freezes when the road cools to below 0°C;
– frost or light snow compacted by trafficking.

For the non-alpine areas of New Zealand, the last two factors will be the more common causes of ice on the roads.

Snow is visible to road users and its impacts can generally be anticipated by RCAs and drivers (e.g. notices advising that tyre chains should be used). If snow falls unexpectedly, it may block the road to traffic until snow-clearing machines clear it. If snow has been forecast, the local RCA's winter maintenance procedures should allow for some preparation in readiness for the snow event, e.g. signs, snow-clearing crews on stand-by (Figures 6-11 and 6-16). Snow-clearing by snow plough or grader can damage coarse textured surfaces, and their drivers need to take care not to damage the chipseal and other road-related assets. Where snow is common, snow blowers which are less damaging to road surfaces may have been bought as part of an RCA's plant.

6.8.3 Hoar Frost on New Zealand Road Surfaces

A study by Dravitzki et al. (2003) examined hoar frost build-up on different road surfacings (both chipseal and AC) in New Zealand. On chipseal, frost was noted to form first on the tips of the chips because, with radiative cooling of the road, the chips are cooler than the deeper bituminous layer of the seal. The frost consists of small granular crystals forming a single layer over the chips. The crystals adhere only loosely to the chips and are easily dislodged.

As the frost becomes more intense, it forms a continuous layer over the chip and bituminous binder. As it becomes even more intense, several layers of frost crystals form. All these crystals are only loosely bound and are easily removed. For example trafficking can dislodge most frost crystals off the tips of the chips so that vehicle paths along the road become apparent.

Frost on smooth pavement surfaces, such as asphaltic concrete, tends to form quite uniformly over the surface. The initial stage of frost forming on the tips of the finer chips is soon superseded by formation of a more continuous layer.

6.8.4 Sites of Frost Formation

A New Zealand study (Dravitzki et al. 2003) found that the single most important factor for most roads outside alpine areas is shading the road by terrain or by trees. Frost appeared to form exclusively at sites where the road was not exposed to the sun for any part of the day, or where exposure, if it did occur, was very brief, e.g. 5–30 minutes.

At these sites, a heavy dew could form in the early evening even if nearby areas were reasonably dry. Frost would then form overnight or in the early morning. Further, because these locations were not exposed to the sun, frost once formed could remain throughout the day on the untrafficked sections and the frost layer could be further thickened by an additional freezing cycle during the following night.

6.8.5 Impact of Frost and Ice on Skid Resistance

The impacts of frost and ice on skid resistance are shown in Figures 6-12 and 6-13. They show the skid resistance in the natural frost and ice conditions measured with the British Pendulum Tester (BPT) expressed as a percentage of the skid resistance in the wet condition, all plotted against texture depth. Although concerns are that the BPT may not show the full effect of the macrotexture in frost conditions, Dravitzki considers it shows the effect of ice conditions adequately. Data points are shown for both wheelpath and non-wheelpath samples which have marked differences in microtexture.

Outliers aside, Figure 6-12 shows that frost conditions reduce skid resistance to 40-60% of the wet skid resistance for pavements with texture depths less than 1 mm, and to 50-70% of the wet skid resistance for texture depths about 2-3 mm.

Figure 6-13 shows that ice conditions reduce skid resistance much more, to only 20-40% of the wet skid resistance for textures less than 1 mm, and to 40-60% of the wet skid resistance for textures about 2-3 mm in depth. This means that pavements with finer texture have lower skid resistance in frosty and icy conditions.

6.8.6 Identifying Locations of Frost Formation

Identifying areas where frost and ice formation are likely to occur is an important task because most of these locations are scattered and occur over only short stretches of road.

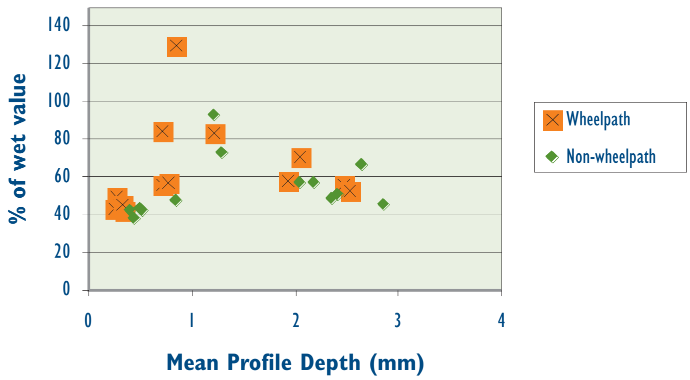

Figure 6-12 Skid Resistance (in BPN) of road samples in natural frost conditions, expressed as percentage of wet value of skid resistance versus texture depth (as MPD mm).

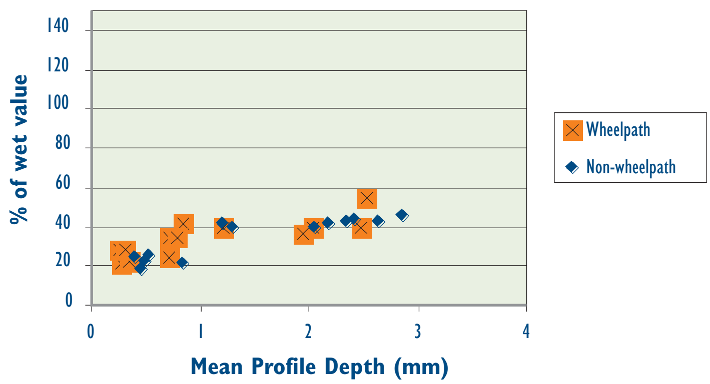

Figure 6-13 Skid Resistance (in BPN) of road samples in ice conditions, expressed as percentage of wet value of skid resistance versus texture depth (as MPD mm).

The most rigorous way to locate these spots, in order to apply appropriate long- or short-term treatments, is a technique known as thermal mapping. Thermal mapping data is developed into a computer model to predict when and where frost and ice are likely to occur. Large numbers of sophisticated warning systems e.g. Road Weather Information System (RWIS) or other systems are required to feed daily temperature and humidity data into the computer containing the model developed from the thermal mapping data. The model then predicts where and when frost and ice are likely to occur in real time.

Thermal mapping along with the RWIS stations and associated software to support it are in use in some places in New Zealand. However, an effective and cheaper option is to identify sites where frost and ice are likely to occur by careful visual inspection and manual recording during winter when the sun is low in the sky. This inspection could also be made in other months if allowance is made for the angle of the winter sun. These areas can then be treated by increasing texture or by cutting back vegetation to expose the road to the sun.

6.8.7 Implications for Road Management

The effect of frost or thin ice is significant in road management because it lowers skid resistance so much. The current skid resistance strategy is to provide increased skid resistance for wet roads, but for icy roads strategies focus more on rapid response for snow clearing and 'just in time' application of grit and chemical de-icers.

6.8.7.1 Minimum Texture Depth

Based on studies using the BPT:

- Low texture surfaces (those about 0.8 mm or less) appear very vulnerable to the effects of frost and ice;
- Deep texture surfaces (those about 2-3 mm) may retain a higher skid resistance than smooth surfaces in frost and thin ice conditions, but the improvement is not large.

Therefore in locations where frost or ice occur intermittently and the extent of this condition is not severe, maintain the macrotexture with a minimum of about 1.5 mm texture depth (measured as MPD) (Figure 6-14).

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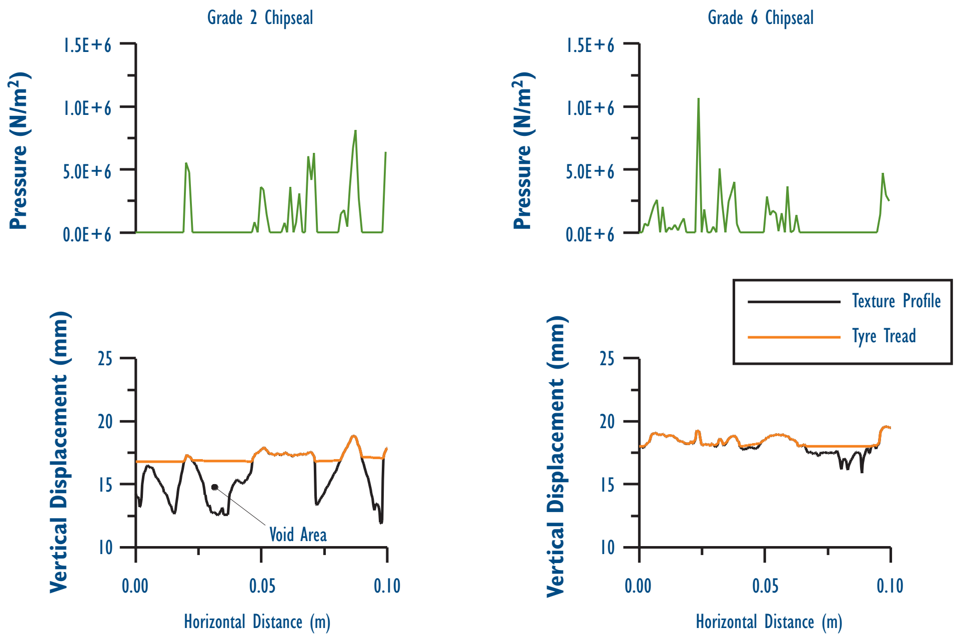
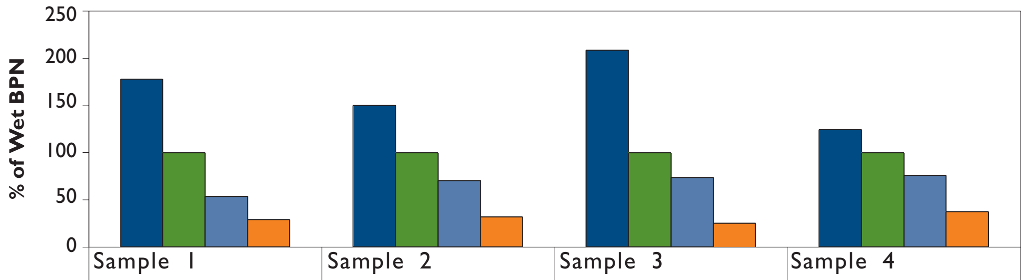


Figure 6-14 Comparing the contact made by the tyre footprint with chip of Grade 2 (coarse) and Grade 6 (fine), and the high point pressures (N/m^2) generated at the high points of the chips.

6.8.7.2 Effects of CMA (Calcium Magnesium Acetate)

In locations where frost and ice occur often, an additional management strategy is to apply CMA as a prevention treatment when the weather conditions and the forecast indicate likely formation of frost and ice. Comparisons of skid resistance under dry, wet, with and without CMA are illustrated in Figure 6-15.



	OGPA	Untrafficked Grade 3	Trafficked Grade 3	Untrafficked Grade 5
Dry	178	150	209	124
Wet	100	100	100	100
CMA	54	70	74	76
Ice	29	32	25	37

Figure 6-15 Comparison of skid resistance measured in dry conditions, in wet conditions without CMA, with CMA, and with ice (without CMA).

Using CMA to provide a higher skid resistance than that of an iced surface offers a paradox as CMA becomes very slippery if wetted, e.g. during a dewy night. In fact the skid resistance of a surface wetted with CMA is lower than of a wet road. For this reason CMA needs to be applied ‘just in time’, i.e. early morning (4am) before the frost forms. In addition, warning signs, e.g. SLIPPERY WHEN WET or SLIPPERY WHEN ICY, need to be issued because of the increased slipperiness caused by CMA.

6.8.8 Resurfacing Snow- and Ice-Prone Roads

Both chipseal and asphalt surfacings for roads likely to be affected by frost, ice and snow need to provide adequate skid resistance under these conditions. Their design should take into account the following matters for reducing the formation of ice or frost on a road, and for maintaining adequate skid resistance in cold conditions.

6.8.8.1 Road Geometry

If the alignment of the road is straight, the risk of loss of control caused by frost or ice may be less. However tight corners and steep gradients offer greater risks if ice forms on them, and the likelihood of skid-related crashes in icy conditions is therefore high. The high stresses caused by turning and scuffing means chip loss has often occurred on those sections as well, offering less skid resistance in cold conditions.

In such locations, asphaltic mixes (Stone Mastic Asphalt (SMA), Open Graded Porous Asphalt (OGPA), asphaltic concrete (AC)) may achieve better value for money in terms of whole-of-life cycle costs, but a minimum texture depth needs to be specified to achieve adequate skid resistance in cold conditions.

6.8.8.2 Chip Selection for Snow-prone Roads

Snow-plough action damages single coat chipseals with high macrotexture, and conversely, uneven rough pavement shape will damage the snow plough (Figure 6-16).

Figure 6-16 Snow clearing with graders and loaders (with wheel chains) can cause damage to the chipseal.

Photo courtesy of Les McKenzie, Opus

Two coat, racked-in, or locked-in type reseals will have less macrotexture but will be more resistant to snow-plough damage, and have their place in snow-prone areas. Seals with lower macrotexture aid thawing of snow and ice, and conversely those which have less chip and more macrotexture will take longer to thaw.

The normal procedure of applying voidfilling to coarse chipseals followed by a coarse reseal at a later date is appropriate for these conditions (see Section 6.5.2).

6.8.8.3 *Binder Selection for Snow-prone Roads*

When designing seals for cold conditions, the normal process for selecting the binder should be followed, keeping kerosene contents between 4% to 6%, so that binder curing is hastened before the onset of the next cold season.

> However because the daily and seasonal temperature ranges are large, the binder needs to have greater adhesion, especially if the seal coat has to be constructed either late or very early in the summer. Use of adhesion agents are therefore recommended.

PMBs may better enable a binder to withstand the high temperature variations of day and night, i.e. to make the binder less temperature susceptible.

6.8.8.4 *Timing of Resurfacing*

Planning the timing of the resealing operation is important, in order to make use of the warmest part of the year. Early sealing (before the Christmas holidays[2]) gives the advantage of better chip embedment through trafficking by the higher volumes of holiday traffic.

> As stated in previous sections, the earlier in summer that resurfacing is completed, the longer is the time available for embedment and curing to take place, and thus the better the chance for a successful seal in the cold conditions likely to occur during the following winter.

> Because the variations in temperatures and weather are high in these extreme environments, the resealing operation should begin when a fine and warm weather window of several days is forecast.

The chipsealing operation should be carried out during the months when the variation between night and day temperatures is least (early summer) as this will help curing. Resurfacing completed after the end of February (late summer), when the daily temperature variation is increasing, may be prone to failure because the wide variation in temperatures slows down binder curing, adhesion and embedment.

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2 The summer sealing season in New Zealand (Southern Hemisphere) spans the Christmas holiday period. Summer holidays (vacation) are generally taken over Christmas and into January.

6.9 Seal Selection for Mitigating Road Traffic Noise

Road traffic noise is generated by traffic travelling along the road, and it is determined by a number of factors, one of which is the type of road surface used.

6.9.1 Sound and Noise

The terms 'sound' and 'noise' are often used interchangeably. However 'sound' is the physical phenomenon of vibrations in the air that we hear with our ears, and 'noise' has a qualitative connotation that is usually applied to unwanted sound.

> Sound from traffic using roads, though measured with a sound level meter, is almost always termed 'road traffic noise' irrespective of the sound level. In practice the levels of road traffic noise which are readily accepted by the community could be called 'road traffic sound', and higher levels that are unacceptable to the community should be called 'road traffic noise'.

6

6.9.2 Sources of Road Traffic Noise

The road surface affects traffic noise by the interaction of the road surface with the vehicle tyre. This complex set of both mechanical and aerodynamic interactions that occur between the vehicle tyre, its tread pattern and the road surface, are illustrated by Figures 6-17 and 6-18 (used with permission from Sandberg & Ejsmont 2002).

Road surface texture and porosity are but two of the factors influencing these mechanical and aerodynamic interactions. The nature of the tyres is also important and, as a consequence, the road surface effects on noise differ for light and heavy vehicles.

The types of vehicles also affect road traffic noise from the sources related to the vehicle engine and body. For example, noise is generated from the mechanical moving parts from the engine and the engine exhaust, from the gearbox and drive shaft, and from the vibration from the engine and underlying road to the vehicle structure, which then radiates out from the metal body.

With modern cars, tyre–road noise is the major contributor to traffic noise at all speeds (Table 6-5). For older cars at low speeds, vehicle motor noise is the main contributor of noise and tyre–road noise has been found to be the major contributor to traffic noise only after vehicle speeds exceeded 70 km/h. The low frequency tyre–road noise is particularly annoying in residential areas. It is largely caused by the coarse (or larger sized) chips, which may be required to achieve adequate water drainage, and be more durable for high-speed situations. Chips of larger size are also desirable to reduce the 'tyre hiss' on wet pavements.

Table 6-5 Relationship of vehicle age and speed as sources of traffic noise.

Vehicle age	Vehicle / Motor Noise	Tyre-Road Noise
Older cars		
<70 km/h	Major contributor	Minor contributor
>70 km/h	Minor contributor	Major contributor
Modern cars (all speeds)	Minor contributor	Major contributor

Finer sized top surface aggregates will reduce the noise generation, but they are less durable and may suffer early failure through chip embedment and flushing, especially under heavy traffic loads.

6.9.3 Noise Impacts and their Measurement

The level of sound is measured by the pressure that the air vibration exerts on a flexible diaphragm (microphone). Sound level is quantified as decibels, symbol dB, which are $^1/_{10}$th of a Bel. Decibels and Bels are not physical quantities but are ratios that compare the pressure of the sound to the pressure of the quietest sound just detectable by the human ear. Sound levels of 50dB, 60dB and 70dB are 10^5, 10^6 and 10^7 times greater than this just-detectable sound.

Sound from most sources is composed of a number of individual frequencies. The human ear is not equally sensitive to these frequencies and the sound level may be adjusted to allow for this difference in frequency, a process called ‘weighting’. This processed level is shown as dBA.

Noise levels are expressed in several ways. One way is the average noise level measured over the day. Common average measures are L_{eq} or the equivalent noise level, or L_{10} which is the noise exceeded 10% of the time. A second way to express noise is to measure the highest instantaneous noise of a passing vehicle, or the maximum noise level (L_{max}). The measure L_{10} can be changed to L_{max} by taking a 1 second average of the high noise levels of passing vehicles, i.e. L_{eq} (1 second).

6.9.4 Community Impacts

The level of road traffic noise is a physical quantity, the significance of which can be assessed in connection with its impact on the community. The impact of traffic noise can be determined by surveying the community, and numerous surveys have now established reasonable relationships between road traffic noise level and community impact.

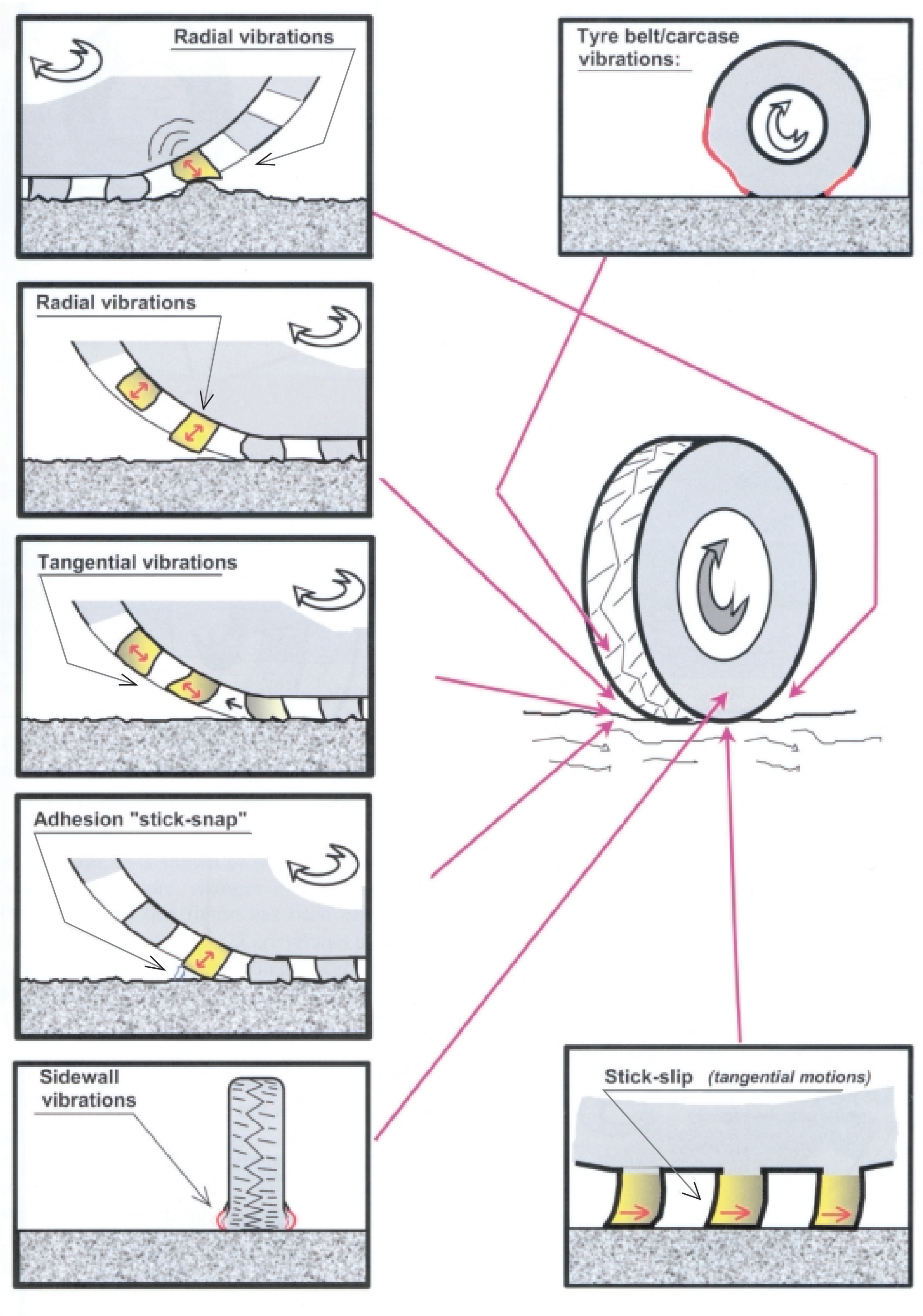

Figure 6-17 The vibration-related mechanisms of tyre–road noise generation (by tread impact and adhesion) (reproduced with permission from Sandberg & Ejsmont 2002).

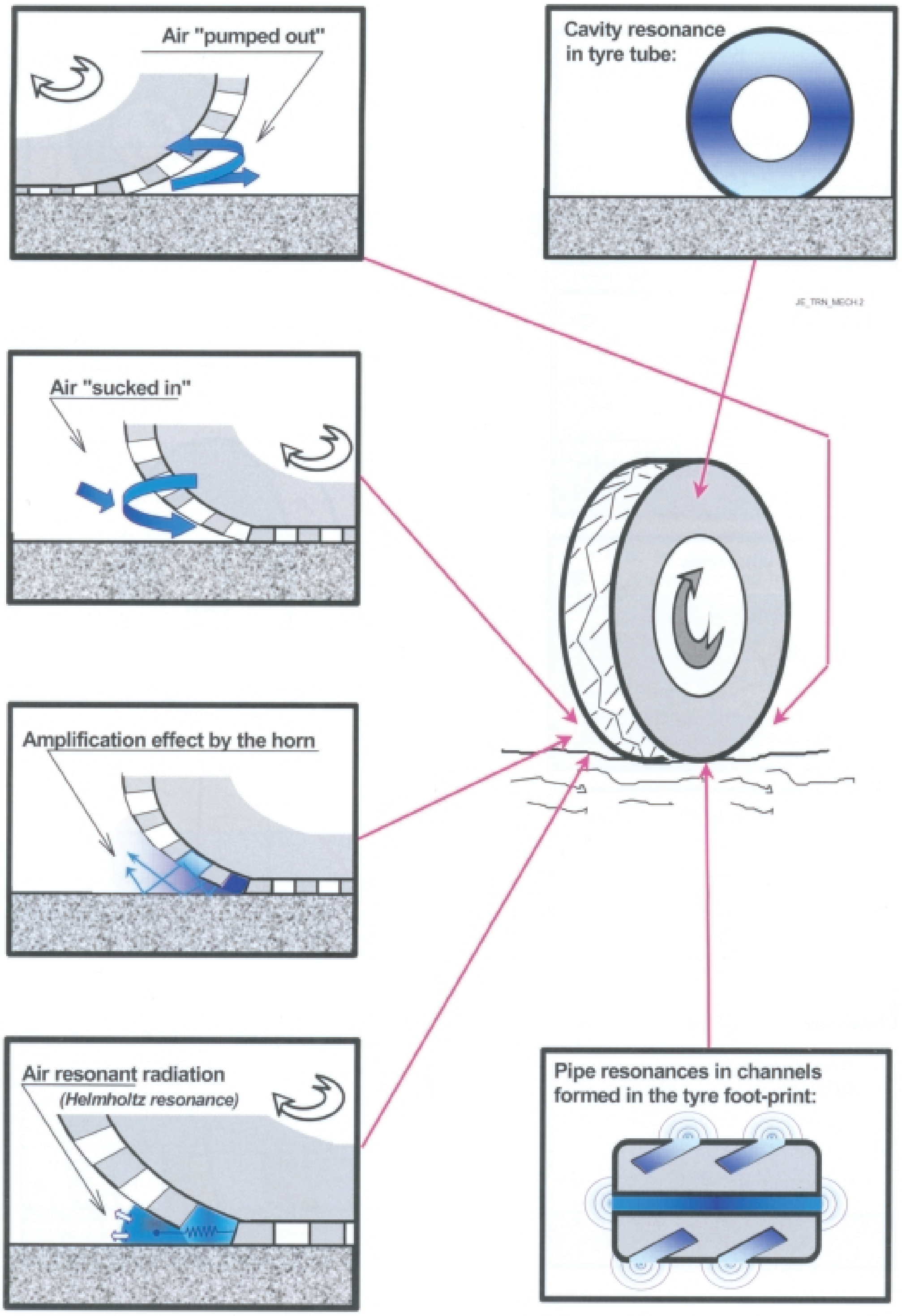

Figure 6-18 Aerodynamic-related mechanisms of tyre–road noise generation (by air displacement) (reproduced with permission from Sandberg & Ejsmont 2002).

Research also shows that, where traffic noise is not loud enough to have direct health effects, it can still have a significant influence on how people feel about their neighbourhood and how they live their lives. People highly annoyed by noise can experience stress and indirect health effects. Noise may also affect how people use their property, and may range from smaller changes, such as turning up radios, to other changes such as discouraging outdoor activities, or having to close windows and doors, or to extremes such as avoiding rooms exposed to peak hours traffic until it has decreased, or even having to re-locate.

The range in noise level between acceptable and unacceptable impacts is only about 25 dBA. Quiet suburban streets have daily average noise levels of about 45-50 dBA, whereas roads such as motorways and busy urban arterials, which are often at the limits of acceptability to the community, have daily average noise levels of about 70-75 dBA. Within this 25 dBA range, up to 10 dBA but more typically 4-5 dBA can be influenced by choice of road surface type.

Surface selection is therefore an effective method of controlling road traffic noise and is one of the few options available to RCAs.

The road surface effect on total noise may seem to be small, i.e. only a few dBA. However this is not the case. Because the road–tyre interaction is the dominant source, most of the daily average level, e.g. 50 dBA or 75 dBA, is from the road–tyre effect. Therefore, altering the surface has the potential to change these levels by 5-10 dBA.

6.9.5 Modelling for Community Impacts of Noise

Modelling for the road surface type indicates expected change only in the physical quantity of the noise. The noise benefits provided by a particular surface need to be balanced against the benefits to the affected community. Research shows that the community impact caused by a change in noise level is dependent also on the existing noise level. A decrease in noise where levels are already high has a greater impact than the same decrease in noise where existing levels are low to moderate.

Annoyance and behaviour are closely related. When a more noisy seal is used with an associated increase in traffic noise, then changes in social behaviour may result.

However, the community response to noise levels differs widely. Surveys show that, as well as the 15% of residents in a busy street who may be highly annoyed by the traffic, and another 25% annoyed, some 15% and 25% will consider the noise level to be very satisfactory or satisfactory respectively. Change in impact therefore has to be assessed against a quite high level of impact, such as the change in the population who are "highly annoyed", or the change in the population who have to significantly change their use of their house, e.g. "changed rooms", or "come home late" to avoid noise.

Table 6-6 shows the effect on the community noise environment of the change in noise that comes with choosing different road surface types. Columns 1 and 2 show the change in noise levels (dBA), and columns 3, 4, and 5 show the extent of improvement for three typical noise environments (of <60 dBA, 60-69 dBA, >70 dBA).

The level of impact chosen is arbitrary. The scale below shows a classification (used in Table 6-6) for the extent of improvement against the baseline percentage of the population that is **acutely affected**:

- a **big improvement** to the noise environment means that the % acutely affected has been reduced by 15% of the total population;
- an **improvement** to the noise environment means that the % acutely affected has been reduced by 10% of the total population;
- a **small improvement** to the noise environment means that the % acutely affected has been reduced by 5% of the total population;
- a **little worse** is a 5% increase in the % population acutely affected;
- **worse** is a 10% increase in the % population acutely affected;
- **much worse** is a 15% increase in the % population acutely affected.

Table 6-6 Guideline (indicative only) for selecting surface types in reseals, showing the change in noise level (dBA) from the baseline % of acutely affected population, against the expected improvement in the living environment.

Change in Noise Level (dBA) related to Road Surface Change		Less than 60 dBA Leq_{24hr}	Between 60-69 dBA Leq_{24hr}	Above 70 dBA Leq_{24hr}
Reduction	More than –3.6	Small Improvement	Improvement	Big Improvement
	–1.1 to –3.5		Small Improvement	Improvement
	0 to –1	Little Change	Little Change	Small Improvement
No Change	0	N/A	N/A	N/A
Increase	0 to 1	Little Change	Little Change	A Little Worse
	1.1 to 3.5	A Little Worse	A Little Worse	Worse
	3.6 and greater		Worse	Much Worse

6.9.6 Road Surface Effects

Effects of road surface on noise are measured by standard techniques (e.g. BSI 1995, 2001a, b) in which the noise levels of vehicles being driven at a steady speed are measured by a roadside sound-level meter. The meter records the sound (noise) level generated at the 1 second in which the vehicle is directly opposite it.

The standards are taken as follows: on a dense asphaltic concrete surface these noise levels are about 68 dBA and 79 dBA for cars and trucks respectively, at 50 km/h, 76 dBA for cars at 100 km/h, and 84 dBA for trucks at 90 km/h. Table 6-7 shows the noise effects of different road surfaces over different speeds for both cars and trucks. This data was obtained in an experimental investigation of the effects of the road surface on noise, undertaken in the Wellington region in 2002 (Dravitzki in prep.).

Table 6-7 Effects of different road surfaces on cruise-by noise levels (dBA) for light and heavy vehicles (cars and trucks), at different speeds.

Speed km/h	Noise (dBA) from Light vehicle (car)						Noise (dBA) from Heavy vehicle (truck)				
	AC	OGPA	Grade 3/5	Grade 3	Grade 2/4	Grade 2	OGPA	Grade 3/5	Grade 3	Grade 2/4	Grade 2
50	68	69	74	74	74	75	77	80	80	-	-
70	72	73	78	78	79	81	80	82	82	81	83
90	-	-	-	-	-	-	82	85	84	84	85
100	-	77	83	83	85	84	-	-	-	-	-

The effect of other surface types on noise is expressed as relative to that on dense asphaltic concrete for each vehicle type. For example on chipseal surfacing, cars are +4 dBA more noisy than on dense AC, and trucks are +1 dBA more noisy. When vehicle speed increases total noise increases, so it is important that surface types are changed to suit changes in the traffic using the road. If a traditional low-speed surfacing is retained for a road on which the traffic travels at higher speeds, the traffic noise increases.

Slurry seals (e.g. Type 3 described in Section 3.8.1) offer a suitable alternative to a conventional chipseal when low traffic noise and a lack of loose chips are important considerations, because reductions of up to 3 dBA (compared with chipseals) are possible. They also offer a coarser texture than dense AC for use on these roads that are more highly trafficked, and on state highways. These are often key reasons for their use in urban or semi-urban situations in shopping, urban or residential areas where road and traffic noise is an important consideration.

Table 6-8 shows differences in noise level for common road surfaces used in New Zealand, using data obtained from Dravitzki (in prep.). The noise effects of different kinds of

Table 6-8 Effects of road surface types on noise, relative to dense AC, for light and heavy vehicles (cars and trucks) travelling at speeds of 50-100 km/h.

Vehicle Type	Dense AC[1]	Standard OGPA[2]	High Voids OGPA[3]	Fine Chip Grades 4,5,6	Med. Chip Grade 3	Coarse Chip Grade 2; Two coat seals
Car/light	0	0	-2	3	4	6
Truck/heavy	0	-2	–	-2	1	1

Notes
1 Mix 10 dense asphalt concrete (AC).
2 OGPA complying with TNZ P/11. 20% voids laid at approx. 30 mm thickness.
3 30% voids (at 40 mm thick). Special materials laid to 70-100 mm may be -4 relative to AC.

surfaces were first measured, then compared to that obtained on asphaltic concrete which is taken as the baseline. Several replicates were made of each surface type, and the surface types with similar effects are grouped.

The values in Table 6-8 have been determined as the composite for new and aged surfaces that are near replacement. Experiments have shown that, over a typical surface life of 7-10 years, the noise effect varies usually by 1 dBA. For chipseals the noise level is highest for the new surface, then decreases with age from a loss of texture. For dense AC the noise level is lowest for the new surface and then increases with ageing, as ageing usually results in a roughening of the road surface.

The values in Table 6-8 therefore are the differences in noise effects of the road surfaces for the main portion of the service life. Different values may be reported from different studies. One local authority reports that their measurements do not support two coat seals being 6 dBA above that for AC at any speed.

6.9.7 Seal Selection for Noise Reduction

Although the effects of the road surface are dependent on the vehicle type, these interrelated effects need to be combined to show the effects for typical streams of traffic. One way to calculate the combined effects is to use a noise calculation model, such as the Nordic model for road traffic noise prediction which calculates the noise produced by the traffic streams separately. (The Nordic model was first introduced in the 1970s as a common road surface noise prediction model used by the five Nordic countries (Sweden, Denmark, Norway, Finland, Iceland). The latest version is given in TemaNord, 1966.)

Table 6-9 has been produced from a series of calculations using the Nordic model to produce the net surface effect for any volume of traffic, with the ratio of light to heavy vehicles identified. Table 6-8 showed that the noise effect of different surfaces at 50 km/h was the same as at 100 km/h, and Table 6-9 can be used for calculating the most appropriate road surfacing for different speed zones, and the roading engineer can use it to assess the effect (or benefit) of choosing one surface type over another.

For example, if a street was already surfaced with Grade 3 chip, and the volume of heavy traffic is low, e.g. 3%, then a significant noise reduction (about 3.7 dBA) could be achieved by using an AC.

However if this street had a high proportion of heavy vehicles, e.g. 20%, then the benefit of using AC represents only a 0.8 dBA reduction in noise, and OGPA would give a greater noise reduction.

Table 6-9 Combined effects of different road surfaces and of light and heavy vehicles on tyre–road noise (dBA) (AC taken as baseline).

% Heavy vehicles	Noise (dBA) generated by light and heavy vehicles on different road surfaces				
	Dense AC	OGPA	Fine chip Grades 4,5,6	Medium chip Grade 3	Coarse chip Grade 2; Two coat seals
0	0	0	3.0	4.0	6.0
3	0	–0.3	3.0	3.7	5.5
10	0	–0.8	1.5	1.5	4.5
20	0	–1.0	0.8	0.8	3.5

6.10 Seal Selection for Environmental and Community Reasons

Sealing activities have the potential to create a range of positive and negative effects on the natural environment and neighbouring communities. However, costly remedial work and unwanted negative publicity can be avoided by considering environmental and community effects early when planning sealing works.

The objectives of RCAs increasingly reflect a commitment and duty to responsibly manage effects on the environment and community. When operating under the RMA 1991, an RCA has a duty to “avoid, remedy or mitigate any adverse effect on the environment”. Under the Land Transport Management Act 2003 (LTMA), Transit New Zealand must “exhibit a sense of social and environmental responsibility” in operating the State Highway network.

Good practice techniques that protect the environment are often cost-effective and easy to put into practice if included at the early stages of a job. They include minimising waste, reducing energy consumption and taking care of run-off and water use. Control of noise, stormwater run-off, and dust also become important issues in urban areas.

6.10.1 Waste Minimisation

Waste minimisation includes consideration of the way waste is disposed of, reducing the amount of waste to dispose of, say at the landfill, and reducing the demand on primary sources of materials, e.g. of aggregates. As planning for waste minimisation is part of construction, ways of achieving it are given in Section 11.7.1.

6.10.2 Energy Efficiency

Taking simple steps to reduce energy consumption can result in cost savings and make a positive contribution to national energy reduction targets. Consider these steps at the planning and selection stage, so that they can be carried out in the construction stage of a chipseal (Section 11.7.2).

For example, greater efficiency and better prices may be obtained if local sealing contractors and aggregate producers are kept well informed of the intended reseal programme as it is developed.

6.10.3 Water Management

The effects of sealing activities on the volumes of water used and impacts of water run-off on stormwater can be reduced through careful water use and sensible management practices (Section 11.7.3).

Key water management objectives include:

- Reducing the volume of potable (drinking quality) water used in sealing and maintenance activities, e.g. for washing down, by turning off hoses when not required.
- Ensuring pollutants from sealing activities do not enter waterways.
- Control stormwater run-off by including catch pits, sumps.
- Filtering and re-using water collected from high pressure water treatments.

Good management practices to minimise contamination include:

- Avoiding spillage of binders, and being prepared for such events.
- Ensuring containment devices are in place and spillage kits (of fine aggregate to cover oily spills, portable textile dams to block run-off) are available.
- Ensuring that fire extinguishers are accessible. RNZ's BCA 9904 recommends that the local Fire Brigade be alerted that the job is under way.

6.10.4 Complaints about Chipseal Standards

Recent research (Cleland et al. 2004) analysing the complaints database of a number of RCAs found that 30% of road surface complaints are about construction. Figure 6-19 displays the breakdown of the seven types of these construction complaints.

The primary construction complaint is about *poor finish* (38.6%), and refers to a work site not being restored to its former condition. This includes construction materials left behind, materials removed but not reinstated after work was completed (such as road markings or signage), and general damage or mess left post-road construction or maintenance.

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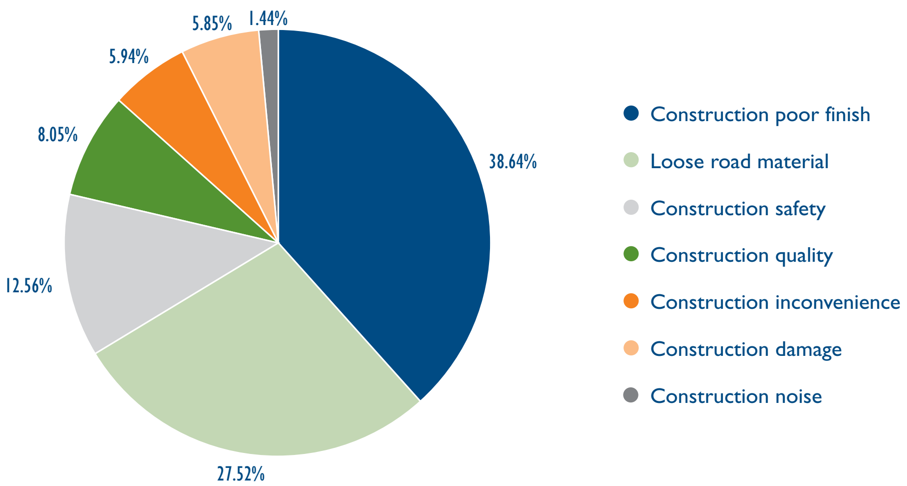

Figure 6-19 Analysis of road construction complaints lodged with RCAs.

Loose road material (27.5%) accounts for the chip or aggregate that comes away from the road surface, and these complaints are mostly made immediately after the construction of a new road seal.

The *safety* of the sites is often questioned (12.6%), particularly with regard to members of the public altering the layout or removing some of the temporary traffic control devices. Within this category were also some complaints made from a pedestrian perspective of work sites.

Although *noise* has strong links to community annoyance (Dravitzki et al., in prep.), noise is the construction feature that is least complained about (1.4%). From the commentary provided in each complaint, those about construction noise were made only when the public felt that the construction was undertaken at inappropriate times, such as late at night or early morning. At reasonable times the public were generally accepting of construction noise.

6.10.5 Community Liaison

> Keeping the community informed about proposed sealing activities can reduce the impact on the community of major interruptions or delays.

Close consultation with the contractor, RCA, road user groups, directly affected neighbours and the wider community should aim to minimise and manage any impacts or disruption of chipsealing on the community. Consultation is important to avoid conflict. The effects of chipsealing on other events needs to be considered, which is elaborated further in Section 11.2 on programming and preparation for sealing day.

6.10.6 Tracking

> Tracking loose chip and binder along roads by vehicles, or into houses and shops and onto other surrounding surfaces by pedestrians, is not desirable, especially in commercial and residential areas.

Tracking is sometimes a serious problem during chipseal construction, but can also happen to the surface later in its life. In principle this type of defect should be possible to avoid by allowing for it in design, construction and maintenance. Economics will dictate the choice of using a standard chipseal or an alternative more expensive treatment that will minimise tracking.

Table 6-10 gives a comparison ranking of the different seal types in terms of binder pick-up and loose chip. A racked-in seal is regarded as the lowest risk option other than a slurry. The racked-in seal has only one application of binder on to the original surface, and the racking in of the smaller chip locks the seal together. Any excess chip can be swept up and removed quickly before it becomes a problem.

On a two coat seal the second application of binder sits on top of the first chip, which creates the risk that the binder can stick to tyres. To minimise this risk of binder pick-up, the second chip is often applied in excess but this creates a situation where excess chip can continue to be dislodged by traffic for months. As will be seen in Chapter 9 the application rates of binder for single coat, two coat and racked-in seals are very similar. Therefore, unless the site stress demands the use of a standard two coat seal in urban areas, either a single coat or a racked-in seal should be considered as the default options.

6.10.7 Appearance and Aesthetics

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> An even appearance to the road surface not only looks good, but is also safer and gives a smoother ride. An even appearance can be achieved with coarse textured surfaces, with less construction effort, than with very fine smooth surfaces.

For example, on a slurry treatment the longitudinal joints are often prominent, whereas at the other end of the scale, on a well-constructed Grade 2 seal the longitudinal joints are often difficult to identify.

Even though the texture depth of a multicoat seal may be similar to that of a single coat seal, the appearance and development of the texture is different (see Figure 11-2).

6.10.8 Pedestrian and Cyclist Preferences

Pedestrians and cyclists dislike using very coarse surfaces. However, with care and consultation, a surface can be designed to provide an adequately smooth surface that retains all the required safety features, e.g. adequate drainage and skid resistance. In pedestrian areas a seal can be constructed using Grade 5 chip. Although this surface may not be regarded as suitable for areas of high traffic volumes, it is a viable option on footpaths. Alternatively a slurry treatment is often used as a re-surfacing treatment for footpaths and other pedestrian areas, especially as a maintenance treatment over asphaltic concrete.

6.10.9 Fuel Consumption and Tyre Wear

The friction from surfaces with good skid resistance causes increased fuel consumption and tyre wear. On heavily trafficked roads, the additional fuel and tyre wear costs are considerable if very coarse chip is used, whereas a less coarse chip will achieve the maximum safety benefits from improved skid resistance, yet with lower fuel and wear costs.

A comparison of the surface treatments for these community expectations is given in Table 6-10, in which the seal types are ranked from 1 best to 4 worst.

Table 6-10 Comparison by rank of four seal types for their effects on environmental and community issues.

Environmental or Community Issue	Single Coat	Racked-in	Two Coat	Cape Seal Slurry
Noise	2	2	2	1
Loose Chip	3	2	4	1
Bitumen Pick-up / Tracking	3	2	4	2
Pedestrians	3	2	2	1
Cyclists	3	2	2	1
Aesthetics / Appearance	3	2	3	1
Fuel Consumption / Tyre Wear	2	2	2	1

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