Recycling of Materials for More Sustainable Road Construction

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Rosslyn Bailey, Vincent Dravitzki, John Patrick
Opus Central Laboratories

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Rosslyn Bailey, Vincent Dravitzki and John Patrick, Opus Central Laboratories,
PO Box 30-845, Lower Hutt, New Zealand.

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An Important Note for the Reader

The research detailed in this report was commissioned by Transfund New Zealand.

Transfund New Zealand is a Crown entity established under the Transit New Zealand Act 1989. Its principal objective is to allocate resources to achieve a safe and efficient roading system. Each year, Transfund invests a portion of its funds on research that contributes to this objective.

Contents

Executive Summary

This research project was carried out in two phases between 1999 and 2001. Its objectives were:

- to identify the economic, structural and attitudinal impediments to the recycling of materials in roading, and
- to identify ways in which the recycling of roading materials could be encouraged.

In the first phase, the international literature was reviewed to establish how far recycling was undertaken in other countries, the types of material being recycled, and how far the technical issues in recycling had been resolved. Direct contact with roading authorities, contractors and recyclers in New Zealand established the materials available for recycling in this country, the extent of the roading industry's preparedness for recycling, and current recycling practices.

In the second phase, the structural processes which control New Zealand road construction were examined to identify how far these may be impeding recycling in New Zealand. A review of the international literature, advice on websites and direct contact with roading authorities identified the ways in which other countries are enabling and encouraging recycling.

A key part of this study was the involvement of an Industry Working Group to provide information and advice to the research team. The group, which drew participants from all roading sectors, helped to identify the industry's knowledge of, attitudes to and techniques for recycling, and how far recycling is possible in New Zealand. They also examined the impediments to recycling, with reference to material quantities, technology, government policies, and contractual and environmental issues, and helped to formulate recommendations for overcoming these impediments and a plan to promote recycling.

The international literature review considered five groups of materials, drawn from both the transport and non-transport sectors, and processes for recycling them. They were:

- asphalt and bituminous surfaces,
- aggregates,
- tyres,
- waste oil,
- waste materials from other sectors.

The motivations for recycling were found to be primarily economic, but several factors influence this:

- cost of disposal,
- cost of new materials,
- material scarcity,
- community attitudes and government policy.

A wide range was found in the extent of recycling practised overseas. Relevant policies, promotional initiatives and sources of technical support in the Netherlands, US, UK and Australia are described.

Recycling in roading in New Zealand is less than in these countries. Some base course is recycled by lime or cement stabilisation in areas where good aggregate is becoming scarce (e.g. Gisborne). Asphalt is recycled by some companies but into lower-grade uses (e.g. driveways, car parks), and only small quantities are recycled into roading. Aggregates from crushed concrete and steel slag are used in limited quantities, mainly in the Auckland area. Chipseal is recycled into the base-course layers in Hawke's Bay. Using waste oil as a dust suppressant is discouraged and most is burnt as a kiln heating fuel. Tyres are recycled, but mainly into matting, drainage areas and equestrian surfaces; none is currently used in roading.

Recycling materials into roads in many parts of New Zealand appears to be limited to trials, and several impediments have been identified.

1. The lack of economic incentive, because landfill charges are still generally moderate, especially for clean fill, and the cost and energy consumption of specialist recycling equipment can be high.
2. Current road maintenance practices result in variable quality of potentially recyclable material along the road.
3. The use of recycled materials is not recognised in many roading specifications, and tenders using recycled materials are usually treated as alternatives, which can disadvantage the contractor.
4. The long-term performance of recycled materials is uncertain. The risk is not shared but borne by the rate-payer or roading consultant; in rare cases the contractor may also take on the risk.
5. The lack of knowledge of and experience with recycling within the roading industry in New Zealand: there is a need to adapt other countries' practices to the New Zealand situation, and a lack of knowledge about the performance of New Zealand-specific materials.
6. There is no national programme for promoting recycling, although a National Waste Minimisation Strategy is being developed for release for discussion in early 2002.

The following final recommendations were formulated after the roading industry's input on the preliminary findings, in discussions with the Industry Working Group.

1. Roading funders and roading authorities should alter their procedures so as to encourage recycling that is economic to take place.
2. The procedures that should be modified first are those which will encourage the recycling of asphalt, crushed concrete and base course.
3. The benefits of recycling to the road user and wider community should be quantified and included in evaluation procedures.
4. An industry plan should be prepared which prioritises materials for recycling, develops an implementation strategy for each type of material, and identifies the needs for demonstration trials and further research.
5. Roading funders and roading authorities should further examine their procedures once the National Waste Minimisation Strategy has been finalised, to identify the need for any further changes to procedures, such as guideline methodologies, or waste minimisation plans prepared by the contractor.

The Industry Working Group emphasised the keen interest in encouraging recycling within the roading industry and recommended the following additional work to assist it in implementing recycling:

- Prioritise recyclable materials and recycling techniques according to their ease of implementation.
- Review existing literature to determine the quantity and qualities of the materials, and develop an implementation plan for each material.
- Produce an "enabling" document/specification.
- Develop an industry "means of compliance".

Abstract

This research project examined the economic, structural and attitudinal impediments to the recycling of materials in roading in New Zealand. It found that, although several materials (e.g. asphalt, tyres, waste oil, base course and aggregates from crushed concrete) could be recycled, little (excepting some base course) is recycled into New Zealand roads at present. The structural process of specifications, tender evaluation and risk sharing are major impediments, along with the lack of knowledge of and experience with recycling within the roading industry in New Zealand. However, the industry believes it could quickly develop recycling and build its expertise if a supportive structural process was established. Based on industry input and a review of international recycling initiatives, recommendations to overcome these impediments are proposed.

1. Introduction

This research project was initiated because, although many of the technical issues about recycling of roading materials had been resolved to the stage where they were ready for trial implementation by industry, little recycling was occurring in New Zealand roading. The objectives were to:

- identify the economic, structural and attitudinal impediments to the recycling of materials in roading, and
- identify ways in which the recycling of road materials could be encouraged.

The project, which lasted from 1999 to 2001, involved two stages. The first identified how far recycling of materials is possible in New Zealand road construction, and how far it is desirable. This stage focused on the recycling of roading materials, and of other materials from the transport sector into roads. The second stage identified impediments to recycling of materials in roading, and the steps necessary to achieve a greater level of recycling.

1.1 Background

When the project was developed in 1999, the New Zealand Government had as one of its 2010 strategies the goal of making New Zealand a more sustainable society. In comparison with road construction in other countries, and with other sectors in New Zealand, sustainability practices in road construction in this country are low. For instance, in Australia AUSTROADS and the Australian Asphalt Pavement Association (AAPA) have produced an *Asphalt Recycling Guide* (1997) and New South Wales has a five-year target to recycle 60% of its asphalt surfacing. The building sector internationally strongly addresses sustainability, and this has started to have an impact on practice here. However, although the sustainability of road transport in operations in New Zealand is specifically addressed in the resource consent process for new roads or road improvements, it is little considered in the construction and maintenance phase.

Roading materials (e.g. aggregates and bitumen) are derived from mineral extraction, and therefore cannot be fully sustainable. However, through recycling, it is possible to increase significantly the extent to which materials are conserved. Yet, although the main opportunity for improvement in current construction and maintenance practice lies in materials conservation, this is not widely practised in the maintenance phase – for example, in resealing roads.

Other sources of materials which are recycled in roads in other countries are the transport sector (e.g. tyres and waste oil) and related non-transport sectors (e.g. demolition materials from the building sector). Much of the technology for recycling is already known in other countries, although it may have to be adapted and shown to apply to the New Zealand situation.

1.2 Outline of Methodology

The methodology for the study was first to review the international literature, to establish how far recycling was undertaken in other countries and what materials were being recycled, and to obtain an overview of how far the technical issues in recycling had been resolved. Direct contact with roading authorities, contractors and recyclers revealed what materials were available for recycling in New Zealand, the extent of industry's preparedness for recycling, and current recycling practices in New Zealand roading. In the next phase the structural processes which control New Zealand road construction were examined, to identify how far these may be impeding recycling. A review of the literature and material on websites, together with direct contact with roading authorities, identified how other countries are facilitating and encouraging recycling.

A key part of the methodology of this study was the involvement of an Industry Working Group (described below) to act as a source of information and advice to the research team.

1.3 Industry Working Group

The Industry Working Group drew participants from across the roading sectors. It helped to identify both current industry preparedness for recycling, in relation to knowledge, attitudes and technology, and the extent to which recycling is possible in New Zealand. It also discussed the impediments to recycling, with reference to material quantities, technology, government policies, and contractual and environmental issues. The group also helped to develop recommendations on how these impediments may be overcome, along with a plan to promote recycling.

Assistance from the roading industry was sought because it was thought that its members would have a much better understanding of the impact of each recommendation on their situation. In addition, the project provided an informal forum for different sectors to exchange views on how recycling may be encouraged, which they may then wish to take up in formal processes. The members of the industry group provided their viewpoints as members of a particular sector of the roading industry, but did not necessarily represent the viewpoint of that sector.

Participants in the Industry Working Group were:

- Bitumen Contractors Association,
- Ministry for the Environment,
- MKL Asphalt Ltd,
- Recovered Materials Foundation,
- Sustainable Resources Ltd,
- Transfund New Zealand,

- Transit New Zealand,
- Waitakere City Council,
- Watson Associates (for J. & J. Laughton),
- Wellington City Council,
- Works Infrastructure,
- Opus International Consultants.

2. Recyclable Materials

This section reviews the materials recycled in the roading industry. Most of the information is derived from overseas research and applications. Five groups of materials, from both roading and non-roading sectors, have been investigated in detail.

2.1 Roading Materials

2.1.1 Asphalt

The recycling of asphalt is not new, having been carried out in a limited way since the 1930s. However, recent improvements in materials technology and construction equipment and techniques, along with growing environmental awareness, have led to a rapid increase in the amount of asphalt recycling.

The process involves stripping some of the existing asphalt, blending the stripped material and reapplying it to the road surface. This can be done either on-site or using previously stockpiled material. The recycled material is normally referred to as Reclaimed Asphalt Pavement (RAP), and is further categorised by the process used: either hot-plant recycling or cold recycling, both of which can be carried out off- or on-site.

In off-site recycling, the milled asphalt is transported to a central plant for stockpiling and subsequent processing. The material is crushed and screened, then recycled back into virgin material at a concentration of up to 40%. This combination of new and recycled material is then transported back to the original or new reseal sites.

With on-site recycling, the material is mixed on the site with additional aggregate and a rejuvenating agent, then reapplied and rolled. There are two main methods of on-site recycling, known as cold in-place and hot in-place techniques.

Cold in-place recycling can be used for both asphalt and chipseal surfacing. The method involves milling the wearing surface and reformatting it as a structural layer, and is applicable to areas where flushing or shallow shearing of a chipseal has occurred. Normally a make-up material (well-graded gravel, usually crushed to a maximum size of 14–20 mm) is laid on the road surface, then both this and the underlying asphalt/chipseal are milled and mixed (a cement powder or emulsion is normally added to the mixture). This material is then re-levelled and compacted, after which two sealing coats are normally applied. The main equipment used in cold in-place recycling is the milling machine.

Hot in-place recycling involves heating the asphalt layer, using either conductive or convective heat transfer, milling the material, combining it with a rejuvenating agent and/or adding virgin material, then applying it back to form the road surface. The equipment used in hot in-place recycling is the plant, which first heats the surface and then mills the top 25 mm, at which point the recycling/rejuvenating agent is added. Another machine, which also contains a hopper for adding aggregate, then mills an additional 25 mm off the surface. The final equipment used in this process is a conventional paving machine. The use of large amounts of heat increases the cost of hot in-place recycling compared with the cold in-place technique.

The AUSTROADS/AAPA *Asphalt Recycling Guide* (1997) recommended that up to 20% of RAP could be incorporated into virgin hot-mix asphalt without any special mixing provisions. The only special requirement was the super-heating of aggregate to ensure an adequate mix temperature.

The main benefit of recycling asphalt, using either method, is the reduction in the amount of aggregate needed and therefore the reduction in cost. Significant energy savings are possible, depending on the amount recycled. Further, more moderate savings result from the reduction in the cost of material cartage, in damage to roads by construction traffic and in pollution, and the preservation of natural resources. Additional benefits reported include the finding that RAP mixtures withstand the action of water better than virgin mixtures. The durability of the recycled asphalt was also found to be greater than for conventional mixtures, although this finding is not widely supported in the international literature.

Table 2.1 highlights the differences in energy consumption between using virgin material and various concentrations of recycled material in road construction. Very substantial energy savings can be achieved if a high concentration of recycled material is used.

Table 2.1 Energy consumed in the production of raw materials for asphalt (Hubert 1987)

Material	**Energy (MJ/tonne asphalt produced)**		
	0% recycled	**40% recycled**	**60% recycled**
Sand	9.1	3.6	1.2
Crushed aggregate	27.7	20	15.6
Bitumen	75.1	47.3	27.8
Rotomilled asphalt	0	8.5	12.7
Total	**111.9**	**79.4**	**57.3**
Energy savings (%)	**0**	**29**	**48.8**

One of the main impediments to using hot in-place asphalt recycling in New Zealand is the costs associated with specialist equipment. The cost of a hot in-place recycling system (based on the value of the New Zealand dollar in 1999) is about US$1.2 million. The justification for high expenditure on recycling plant usually relies on landfill disposal costs being also high.

Hot in-place recycling trains, which usually consist of four or five vehicles, can be long (40–60 m) and not easy to work in short suburban streets, although much of the asphalt is in urban areas. A further issue, not discussed in the scientific literature but reported in a Canadian newspaper, is that hot in-place asphalt recycling generates a substantial plume of smoke (possibly similar to the road-burner). If this is typical of the process, it could restrict the use of hot in-place recycling, just as use of the road-burner is already restricted for environmental reasons connected with this plume.

One of the main factors inhibiting use of RAP is the variability in its performance once laid. This is based in part on the limitation on situations where it is considered suitable. Roads with certain alignments, extensive patching and base course-induced defects are considered unsuitable for RAP.

Although RAP is not currently being used extensively in major roading projects across New Zealand, most of the milled asphalt is being reused, as fill material in industrial and low traffic-density applications through smaller roading/driveway contractors.

Cold in-place recycling of chipseal is confined mainly to Hawke's Bay, where it is a good solution to particular problems there.

2.1.2 Aggregate

The review was confined primarily to the use of aggregate material in the base course, sub-base and as bitumen-bound chips on the road surface. The small amount of literature available on recycling of road aggregates concentrates on stabilisation of the aggregate. Most of the literature focuses on the recycling of materials from other sectors for use in base and sub-base aggregate, such as steel slag, concrete waste, RAP, building rubble and rubber tyres.

With increasing restrictions on the establishment of new quarries, and the reduction in the quality of aggregate available in some areas, the quantity of aggregate available in the future is likely to be limited. This has led to the use of marginal aggregates, which generally have a higher proportion of fines or are weaker and so more susceptible to failure. Direct benefits can therefore be obtained in the recycling of aggregate where quality aggregate is in limited supply. In addition to conserving natural resources, extending the life of landfills and reducing transport costs, the recycling of aggregate helps local authorities to achieve recycling/reduction goals and meet public expectations.

Instead of excavating the base and sub-base aggregate for disposal at a landfill, and replacing it with virgin aggregate, it can be stabilised using lime or cement powder. These two techniques appear to be the most common in New Zealand. Research into the use of fly-ash, fibres and geotextiles as other ways of stabilising the base course has increased in the past five years. However, New Zealand has made limited use of these.

The stabilisation of aggregate should help to rectify any deficiencies in soil properties, enabling it to be used in road construction. There are numerous potential uses for recycled aggregate, including as base course and sub-base in low traffic-density areas such as shoulders, as gravel on unsealed roads and backfill for bridge abutments. However, where the aggregate is marginal or contaminated with a high proportion of fines, it cannot be reused in the road pavement without possible structural problems recurring. This material is usually disposed of at landfills.

Some research has been done in New Zealand on the use of marginal aggregates in roads (Dodds et al. 1999), with the use of lime and cement stabilisation appearing to be common practice since the mid-1960s (Hudson 1996).

Problems have been caused in the northern and eastern areas of the North Island by the use of marginal quality aggregate. This aggregate is generally not suitable for recycling within the roading environment and is usually disposed of at landfills. In other areas, however, the aggregate usually has the potential for recycling.

The additional equipment needed to recycle the pavement's base material is usually only that necessary to mix the required amount of stabilising agent into the aggregate. Where the aggregate is contaminated with fines, suitable equipment for washing to bring it up to industry standard would be needed before the aggregate is placed.

In Australia, RAP has been used to produce savings in aggregate resources. Here crushed asphalt (left unbound without any additional treatment) is used as part of the base course and sub-base. The use of crushed RAP is considered uneconomic from the perspective of lifecycle costs. The energy costs associated with crushing the bitumen have a greater value than that obtained by using RAP simply as aggregate. However, compared with disposal at landfills, this form of reuse is preferable.

In the United States, various state transportation departments have introduced legislative requirements that roads contain a proportion of recycled materials or that a certain percentage of some waste materials is recycled. In Australia, 75% of the base and sub-base course is recycled.

2.2 Transport-related Materials

2.2.1 Tyres

It is estimated that 2.5 million waste tyres (1.3 million in Auckland alone) are generated annually in New Zealand. These tyres, which are not retreaded or crumbed for other uses, are usually disposed of at landfills.

Numerous potential uses of the rubber exist. In the roading sector, tyre rubber has been used as a binder, an aggregate material, for roadside drainage and in other roadside structures. Bitumen and ground rubber have also been used for crack and joint sealing in the pavement. A bitumen/rubber binder can be used as an effective stress-absorbing membrane, with the membrane reducing the propagation of pavement cracking. Applications also exist for rubber mixes to be used in high-stress environments, and as open-graded asphalt, or for roads prone to ice formation. Potential uses outside the roading industry include as drainage material in landfills and light-weight backfill in retaining structures.

The use of rubber in bituminous applications depends on the condition of the rubber, its type, volume, particle size and morphology, as well as blending conditions, bitumen chemistry and the type and quantity of additive used. Patrick & Logan (1996), in a literature review of the use of tyre rubber in bituminous pavements, found that two main processes were used to incorporate ground rubber into bituminous surfaces: wet and dry. In the wet process, crumb rubber is mixed with bitumen at high temperatures, and the product can then be applied as a sealing binder or used in a hot asphalt mix. The wet process is more costly than the dry, as it requires special equipment. In the dry process, crumb rubber is added to the aggregate before the asphalt mix. In general no special equipment beyond a calibrated feeding system is needed for this.

The production of crumb rubber also requires special equipment. Tyre rubber itself, let alone the canvas casing or metal belting, is quite abrasive. The rubber is normally shredded using special cutting blades, or cooled using liquid nitrogen and then shattered. The costs associated with such operations are usually the inhibiting factor.

The main processors of used tyres in New Zealand are J. & J. Laughton, who process 500-600,000 tyres per year, all of which are shredded into varying sizes. The company is currently commissioning equipment to produce crumb down to 1 mm. The material is used for drainage or cover in landfills, and potentially in road construction. Other uses include equestrian arenas, farm tracks, gun club embankments, drainage and playground matting.

In the United States, 1% of scrap tyres are used as a crumb-rubber additive in asphalt applications. The US Intermodal Surface Transport Efficiency Act 1991 required the incremental recycling of old rubber into roads.

In New Zealand, very little effort appears to have gone into the use of crumb rubber in road construction. Patrick & Logan in 1996 found insufficient information available on the cost-effectiveness of using crumb rubber in pavement construction, and trials would be needed to assess the benefits. Some trials have been carried out by local authorities and contractors. Waitakere City Council and Auckland Regional Council were involved in roading trials during the 1990s. Blacktop Construction Ltd trialled rubberised bitumen on the Auckland Harbour Bridge, with limited success. Some rubber material is being used for joint expansion in bridges and on some maintenance-hole covers.

The costs associated with using rubber in roads are significantly higher, sometimes up to 50% (Patrick & Logan 1996), than for roads made without recycled rubber. However, indications are that more typical costs associated with the use of crumbed rubber in asphalt pavements are only 5% to 10% higher than for conventional pavements. The shredding/crumbing process requires specialist equipment with high maintenance costs in the replacement of blades. The extra cost seems to be one of the main factors inhibiting the recycling of rubber into roads in New Zealand.

However, the use of rubber-modified binders in rehabilitation projects has proved very successful overseas, with rubber treatment extending the life of the pavement. Using this method to stabilise a pavement due for rehabilitation does not require the excavation of the sub-base or base courses, as is normally the case with traditional rehabilitation methods. It therefore reduces the cost of the rehabilitation of a road while improving the surface characteristics.

In addition to cost, Patrick & Logan (1996) recognised that environmental factors, such as air emissions and processing problems (the rubber can clog plant), may further impede the use of waste rubber in roading.

The recycling or reuse of tyres in other areas offers direct benefits to the roading industry in improving road durability, as well as improving environmental sustainability. The removal of tyres from the waste stream helps extend the life of landfills and eliminates future problems caused by leaching and by tyres rising up to the landfill surface. However, given the extra costs and other factors outlined above, changes in policy or legislation are likely to be the main driving force in the use of crumbed rubber in New Zealand roads.

2.2.2 Waste Oil

Approximately 30 million litres of waste oil is generated annually in New Zealand (Ministry for the Environment 1997a). Of this, 23% is refined and sold back into the market, 16% is burnt and 13% used in dust control, with the remaining 14.4 million litres either dumped at landfills or lost into the environment. The environmental benefits of recycling waste oil are significant. By reducing the volume of waste oil entering a landfill, the hydrocarbon content of the landfill leachate will also be reduced.

There are two main oil recovery programmes in New Zealand: the Used Oil Recovery Programme (UORP) and the Mobile Oil Recovery Programme (MORP). The UORP recommended the development of a nationwide collection programme ensuring that the used oil collected meet strict environmental standards, with oil delivered to approved end-users. Most of the oil recovered from both programmes is used as fuel at the Milburn Cement works in Westport, which has a resource consent to burn used oil to fire its cement kilns. Other users of waste oil include Industrial Engineers in Christchurch, who refine it to produce various grades of oil (hydraulic oil, cutting oil, etc.), as well as a fence stain derived from it.

Opus Central Laboratories undertook research in the early 1990s into the use of waste oil distillation bottoms in bitumen (Herrington 1991, Herrington 1992, Herrington et al. 1993a, Herrington et al. 1993b, Herrington et al. 1997, and Herrington & Hamilton 1998). Although the research showed the use was feasible, Dominion Oil, the source of the waste oil distillates, has ceased operation, removing the source of distillate material.

There is some use of waste oil for dust suppression in New Zealand. This practice tends to be in rural areas, such as Whangarei, Tasman, Gisborne, Bay of Plenty and parts of Hawke's Bay, and is carried out predominantly by private companies.

Over the past five years the Ministry for the Environment (MfE) has been involved in assessing the environmental effects of using waste oil as a dust suppressant (MfE 1997b). As there is little or no treatment of the oil, the possibility exists not only of soil contamination but also of other contaminants entering the environment. In the short term, accumulation of contaminants is considered unlikely to become significant for the adjacent land. Continuous application of used oil will, however, continuously raise the amount of toxic chemicals present in the environment, possibly exceeding acceptable levels. The final fate of these contaminants, some of which are persistent, cannot be controlled. In cases where the application of used oil has been allowed subject to certain conditions, it has been found difficult to adhere strictly to these conditions and to avoid all adverse environmental impacts.

The main equipment associated with the reuse of waste oil is for refining the oil, and for any other filtering to remove contaminants. Where the oil is uncontaminated, refinement is a relatively simple process. However, a large volume of municipally derived oil (collected from public sources) is likely to be contaminated, and is therefore used mainly in combustion processes.

Costs associated with the collection of waste oil are currently minimal, as the material is classified as non-hazardous. Recent investigations into the composition of waste oil collected at service stations indicate that it contains other waste liquids such as solvents. This lowers the flash-point of the oil, requiring special collection facilities in order to reduce the combustion risk to the public. However, the calorific value of oil is such that its reuse as a fuel is more economic than disposal, either at landfills or as a dust suppressant.

2.3 Materials from Other Sectors

The range of waste materials from sectors other than transport which can be used in roading is large. This includes materials which are currently collected for recycling: construction and demolition wastes; ashes and slags; and non-typical wastes such as cellulose from wood and crop stubble. International research has shown that some of these materials can be used in the roading industry.

The economic benefits to the community of reusing waste materials that would normally end up in a municipal landfill or as cleanfill are large, but the benefit in roading costs will depend on the circumstances. Given the increasing pressure on land use, which is resulting in fewer landfills, and the higher costs associated with the design and closure of landfills, the disposal of large volumes of industrial waste is becoming less attractive.

Municipal waste materials collected for recycling include glass, plastic, waste oil, green waste, paper and cardboard. For example, 220,000 tonnes of plastic are generated annually in New Zealand. Where the waste plastic is collected, most of it is either sold to plastic suppliers for recycling as feedstock or dumped in landfills. The Recovered Materials Foundation in Christchurch has been instrumental in reusing glass in floor tiles and other applications.

The recyclable materials within the municipal waste stream are normally separated out by local householders, although some is also done by the collection contractor. Most of the recyclable material is sold on the commodities market, and is primarily exported for recycling into various products.

The MfE and some regional authorities have attempted to address the amount of material being disposed of in landfills. Section 2.3.1 of this report discusses how concrete recycling as aggregate is occurring in some parts of the country. Section 4.6 summarises the MfE report *Towards a National Waste Minimisation Strategy for New Zealand* (MfE 2000).

2.3.1 Construction and Demolition Materials

Construction and demolition waste, which includes crushed concrete and bricks, and general demolition debris and bituminous materials, has a high potential for recycling. Most construction and demolition waste is disposed of as clean fill at local authority or private landfills around the country.

Construction waste is generally disposed of by the building contractor or through a private waste company. It is commonly used as cover material for landfills, or as backfill. In New Zealand the waste is generally not sorted at the source, as it is in some other countries. Some local contractors do, however, separate demolition waste at cleanfill sites, although this process is labour intensive. Source-point sorting would enable reuse of the waste material. The equipment used in sorting construction waste is predominantly screens.

In California, waste Portland cement concrete and dense-graded asphalt are regularly used as aggregate in road base-course construction. The equipment required is normally a crushing plant, with a hopper which receives the waste material, a jaw to break the material into manageable pieces, a cone or impact crusher to reduce the aggregate size further, a vibrating screen for sorting, and a conveyor belt with a rotating magnet to remove any metal (Californian Integrated Waste Management Board 1999).

In New Zealand, Winstone Aggregates in Auckland prepare aggregates from crushed concrete as a standard product line, and are active in developing specifications for this. The use of recycled concrete aggregate in road construction is slowly increasing here, with Materials Processing Ltd operating a mobile crusher and screener. Jukes & Sons also provide concrete as aggregate.

In recycling construction and demolition waste for use as aggregate, care must be taken to remove any metal. This may require the use of magnets.

2.3.2 Slags and Ashes

Other recyclable materials on which research has focused are slags and ashes, such as blast-furnace slag, steel slag, pulverised fuel ash, foundry sand, colliery spoil and slate waste. The water content or water infiltration of the slags and ashes must be considered, as swelling may occur.

Blast-furnace slag is a by-product of pig-iron manufacture. The slag is typically a combination of silica and alumina compounds with calcium and magnesium oxides. Air-cooled blast-furnace slag can be used for embankments and in the sub-base of pavement structures or incorporated into bituminous surfacings. Granulated blast-furnace slag has been used internationally as an aggregate in concrete formation, and in base and sub-base road construction. The use of blast-furnace slag in sub-base construction does not generally require any special equipment.

Steel slag has been used in trials on New Zealand roads. However, it does not appear to be combined with bitumen, as is done overseas, but is used in sub-base construction.

Pulverised fuel ash is used overseas as an additive in base-course construction and concrete, but is not readily produced in New Zealand.

3. Recycling in Other Countries

Several recyclable materials have been identified in Section 2. Most of the technical experience with these materials occurred overseas. Also of interest for this study are the recycling practices, policies and incentives in other countries. Accordingly, a review was done of recycling in the United States, United Kingdom (particularly TRL research), Netherlands and Australia, particularly in New South Wales (NSW) and Victoria.

The use of recycled hot-mix asphalt and recycled concrete is on the increase in many countries, and in some is extensive. Possible ways to recycle on-site are being investigated, and research in the US is examining the possibility of recycling recycled asphalt and whether it can be recycled a number of times.

A tendency to abandon empirical tests in favour of performance-related tests was found. It should be noted, however, that by-products which contain potentially leachable chemical compounds or metals may present a hazard to the environment. Recent research indicates that encapsulating such by-products in asphalt or cement concrete provides particles with a protective membrane that should minimise the potential for environmental hazard and enable these materials to be used in surfacings.

Many of the impediments to, techniques and incentives for recycling were found to apply to all countries, with some local variation. For example, in countries where space is at a premium or good quality materials are in short supply, it will be more economic to recycle. In other countries it may be public opinion and legislation which promote recycling. Many of these specifications and recommendations could be used in New Zealand, provided they are reviewed to ensure their relevance and adapted as necessary.

This findings of this review are detailed below.

3.1 Technical Processes, Guidelines and Specifications

In the US, most states use or support the use of RAP in road construction. However, it is the various state transportation departments (DOTs) which usually determine the recycling of roading materials. Some states also have a proactive approach to the use of other waste material in road construction. Research is carried out into the use of waste materials and recycled road materials in road construction.

The Recycled Material Resource Center (RMRC) has been established by the University of New Hampshire under the Transportation Equity Act (TEA-21). The advisory board includes representatives from the Federal Highway Administration (FHWA), Environmental Protection Agency (EPA), New Hampshire DOT, American Association of State Highway and Transportation Officials (AASHTO), Association of State and Territorial Solid Waste Management Officials (ASTSWMO), industry and highway trade associations. The centre is funded by the FHWA at a cost of US$1.5 million per year for six years.

The RMRC mission has two aspects: research and outreach. The major research-oriented goals are to:

- test, evaluate and develop guidelines for use of recycled materials,
- analyse the long-term performance of highways containing recycled materials.

The major outreach-oriented goals are to:

- make information available to clients (e.g. state or local DOTs and environmental agencies),
- work with officials to reduce institutional barriers to the use of recycled materials in highways.

The RMRC publishes a quarterly newsletter detailing the work done on the various research projects to date. It is likely to be a useful source of information for those concerned with recycling in roading.

In the UK, investigations have been done into the use as roading materials of recycled colliery wastes, china clays and spent shale-oil, as well as the more common wastes.

The recycling or reuse of secondary materials is common practice in the Netherlands, which has the most comprehensive recycling programme of the countries studied (an AASHTO scanning tour found recycling rates of almost 100%). This has been given a strong impetus by the country's special circumstances. The Netherlands has a high population density and limited land. Influenced by government and private-sector information campaigns, public opinion has elected not to use the limited land resources for landfill or aggregate mining.

Several legislative initiatives contribute to the framework for sustainable road construction. The Dutch government provides clear and well-researched engineering and environmental standards for all recycled materials. Public or industry working groups, including contractors, co-operate to achieve these standards. The producers of recycled materials treat them as products, using certified quality assurance and quality control programmes, so that recycled materials can compete with virgin materials. Policy, planning and implementation are clear, allowing producers and contractors to prepare for this new market. There are some incentives from the government to reuse materials that might otherwise be categorised as waste, such as high landfill disposal taxes on recyclable materials, and taxes on the use of new aggregates.

In Australia, the recycling of asphalt and concrete occurs on a large scale, with asphalt recycling promoted by state governments, the national roads board and local government. Reclaimed road base and sub-base material is also used, for example, in stabilised base or as fill.

Specifications for virgin materials used in these countries are quite similar. However, national versions tend to vary somewhat from common standards such as those set by the American Society for Testing and Materials (ASTM). In most cases, specifications and guidelines for recycled materials are available. However, the construction materials and specifications used by these countries can be quite different, as they are based on the historical development of mixes used and the type, characteristics and availability of raw materials.

The report *Recycling Strategies for Road Work*, issued by the Road Transport Research section of the Organisation for Economic Co-operation and Development (OECD) (1997), presented, in principle, three options which should be considered when developing contract specifications for highway construction using road by-products.

1. Use the same guidelines and specifications as for virgin materials, without modification.
2. Use modified versions of current guidelines and specifications for virgin materials.
3. Develop new guidelines and specifications for by-products.

Option 1 is appropriate for by-products that do not differ substantially from conventional virgin materials (e.g. when unbound granular material is recovered and recycled as unbound granular material).

Option 2 should be used where technical guidelines and specifications for recycled material are essentially the same as those for conventional virgin material, but additional constraints (e.g. purity requirements, and limitations on the maximum allowable quantity of the by-product) require modifications or additional provisions to the normal guidelines and specifications.

Option 3 applies to non-traditional applications or combinations of materials such as mixes of reclaimed asphalt, cement pavement and unbound base. The final product should meet the same performance criteria as for virgin materials.

3.2 Environmental Issues

Often the use of by-products in road construction takes place indirectly, through local environmental agencies regulating the quality of soil, surface water and drinking water, as well as other laws and regulations intended to safeguard food and health. The 1997 OECD report noted that, generally, few or no restrictions exist on the recycling of road by-products which have properties similar to the conventional virgin materials used in road construction. The few limitations noted relate to impact on human health (e.g. air pollution during construction) and impact on the natural environment. One example given was that the recycling of coal tar in hot mix is not permitted.

In the Netherlands, the environmental requirements are based on the laws to prevent pollution of the soil and surface water. The approach is complex, taking as its starting-point that the natural concentration of chemical elements and chemical combinations may not be increased in the top metre of soil by more than 1% of the natural background concentration during a period of 100 years. This applies only to leaching of inorganic materials; for organic materials, only compositional criteria are given, in the absence of reliable leaching tests.

In the US, there are no specific environmental quality standards for RAP used in bituminous pavement. Air quality issues for hot-mix plants are generally addressed by state and federal environmental agency statutes. The leachate from reclaimed concrete material appears to be neither toxic nor hazardous; however, when such material is used as unbound base or fill, precipitates from leachate may clog subdrains and geotextile membranes.

In the UK, much of the legislation governing recycled materials is in the Environmental Protection Act 1990. The regional highway authorities are required to consult environmental agencies about possible effects of road building on both ground and surface water. As a consequence, waste materials with water-soluble components are not permitted to be used in fill below the water-table.

At the 1995 workshop on pavement recycling held by AUSTROADS and the NSW Roads and Traffic Authority (RTA), a paper, *The Move Towards Recycling* (Hall 1995), was presented detailing suggestions by the Australian Environment Protection Authority (EPA) on ways forward and opportunities for reusing construction and demolition waste. An action plan containing initiatives to address some of the current barriers to increased recycling was presented.

3.3 Information Sharing – Internet Search

An Internet search was made of the main Australian transport and government sites of NSW and Victoria to review the specifications, policies and incentives available.

Several web sites offered information on incentives to recycling. "Ecospecifier" (http://ecospecifier.rmit.edu.au/info_fm.htm) aims to help architects, designers, builders and specifiers source commercially available, environmentally preferable materials. "onSITE" (http://onsite.rmit.edu.au) is also dedicated to construction and demolition waste, with the aim being:

- To develop a World Wide Web site which consolidates information resources on construction waste minimisation and to make the Web site freely available and accessible.
- To facilitate information exchange and the sharing of knowledge, experiences and data between industry stakeholders.

Both sites are part of the education information provided by RMIT University and offer useful links to other sites as well as downloadable brochures and manuals.

Waste wise is a publication by the Local Government and Shires Associations of NSW, and provides information on general recycling as well as on council projects, the EPA and local government. Information on the regional waste bodies and forums is included, along with reports on recycling initiatives and technology.

The NSW EPA's website (www.epa.nsw.gov.au) provides information on the Industry Waste Reduction Scheme, which was developed from the NSW Waste Minimisation and Management Act 1995. The underlying principles of this Act were to:

- achieve by the end of 2000 a 60% reduction in the amount of waste disposed of in NSW (based on 1990 disposal rates), and
- establish a waste management hierarchy of the following order – avoidance, reuse, recycling, reprocessing and disposal.

The Industry Waste Reduction Scheme was designed to provide flexibility and enable different industry sectors to develop their own best solutions rather than prescribe a single approach to fit all sectors.

The EPA website also provides links to the waste boards active in each region of NSW. The waste boards cover all waste and aim to meet the state's principles and objectives for waste minimisation and management, with each board being required to produce and implement a regional waste plan, along with an annual report. Seven recycling programmes have been developed, dealing with the following aspects:

1. administration, legal and regulation,
2. education, infrastructure and services,
3. market development,
4. research and development,
5. data monitoring and review,
6. waste flow,
7. differential pricing.

The waste boards have also published a number of documents, such as guides for development applications. These publications are downloadable as easy-to-read brochures which appeal to both industry and domestic users.

A "waste exchange" has also been developed from a waste board initiative. As part of the "Waste Challenge", the NSW EPA has provided funding and support to establish the Illawarra Waste Exchange serving the Illawarra region. Designed to mobilise the community to minimise waste (household, commercial and industrial, building and demolition), the waste exchange is a free service. It works on the principle that someone else may have a use for your waste and vice versa, and therefore you "exchange" your waste.

In Victoria, "EcoRecycle" (www.ecorecycle.vic.gov.au) provides downloadable waste minimisation tender guidelines, including what information tenderers should provide as part of their submissions. The key criteria that must be addressed are:

1. innovative practices to eliminate or minimise waste,
2. promotion and use of recycled, recyclable and restored material,
3. recycling of material generated,
4. litter abatement,
5. safe disposal of unavoidable waste,
6. fulfilling all other necessary environmental requirements.

Also available is information on recyclable materials and regional industry waste reduction programmes.

The National Asphalt Research Co-ordination Group (NARC) makes available an industry letter in Victoria on asphalt research. The ARRB (formerly Australian Road Research Board) website (www.arrb.org.au) details a number of NARC projects, with a current research project on asphalt recycling summarised.

A similar search was made of New Zealand sites. Some give general information about what is being recycled, and what can be bought or sold. However, there is little information on these sites about recycling roading materials or construction and demolition waste. This study found no online information for contractors or consultants on, for example, the use and trials of recycled materials.

3.4 TRL Research Project

3.4.1 Background

Research being carried out at the Transport Research Laboratory (TRL) in the UK focuses on the possible barriers to recycling. Some of these are:

- environmental factors – e.g. release of contaminants such as dust, pollution of watercourses, disruption to habitats,
- economic factors – e.g. pressure of time and money,
- cultural factors – e.g. "we've never done it like that before",
- others – e.g. over-prescriptive specifications, inappropriate conditions of contract, environmental regulations.

The overall aims of the project are to increase the quantity of construction materials reused in transport infrastructure renewal works, and to minimise the environmental disbenefit associated with the management of construction materials and waste during such works. The project was due to be completed in October 2001.

3.4.2 Initial Findings

It was found that the major problem in many cases is the definition of waste, and the implications of this in terms of requirements for a waste management licence or an exemption from the licensing regime. The legal definition of waste derives from the European Commission Directive on waste (91/156/EC), in which it is the intention of the producer rather than the nature of the material which determines whether the material is waste or not. Thus a material may be waste in one situation but not in another.

Another factor is that many specifications do not allow for the use of alternative materials. This overlaps with another problem, the lack of awareness of recent developments. A number of publications on alternative materials and recycling have been produced, outlining how the materials can be used together with design guides and specifications.

The project summary concludes that, for most of the problems identified, solutions may already be available and, for others, suggestions on how to overcome them have been made. Sustainable construction was stated to be an achievable goal, but will require action by all the stakeholders in the industry.

4. Successful Strategies Used Internationally to Promote Recycling

In 1997 the Road Transport Research section of the OECD produced the report *Recycling Strategies for Road Works* (OECD 1997), which provided very useful guidance for moving the roading industry towards recycling as the norm. The report, which investigated recycling policies in different countries, noted that there are many reasons for using recycled materials, including:

- the exhaustion of raw material resources,
- the shortage of land that can be used as landfill sites,
- soil and air pollution,
- conservation of energy,
- technical advantages,
- economic advantages.

The report discussed the roles of policy, market forces, leadership and promotion in encouraging recycling.

4.1 Policy

The report found that, in the policy area, regulations that reduce the production of waste and control its disposal can be used. However, the regulations have to be balanced by legislation that encourages sorting, recycling and reuse.

The report noted that, in the Netherlands, policy lines are given in the National Environment Policy Plan, in which sustainable development is the leading issue. For by-products (the preferred term), the decisions to be made are (in order of priority):

- to prevent by-product generation,
- to reuse by-products for the same application,
- to reuse by-products for a different application,
- to incinerate by-products,
- to place by-products in a landfill.

Land in the Netherlands is at a premium, and therefore social pressure to reduce the use of land for dumping is high on the political agenda.

Policy is not set by the government alone. In order to get new policy and its implementation accepted by all parties in the construction industry, discussions take place in the Environmental Platform for the Construction Industry. In 1993, the Environmental Platform published a report on the National Environment Policy Plan called "Policy Declaration on Environmental Targets for the Construction Industry 1995", which presented its policies for the future. These were:

- use fewer raw materials,
- do not use materials with serious environmental effects or unknown environmental qualities,
- reduce the volume and separate the collection of demolition and construction waste,
- regulate the treatment and transportation of waste which is not suitable for reuse,
- impose waste tax on disposal and incineration,
- increase and improve sorting and recycling,
- increase and improve energy recovery,
- stimulate the use of secondary materials,
- stimulate research and use of new materials.

According to the report, in countries where land is not at a premium, the policies may show some variation, but should follow the same lines. In order to monitor results, most countries set goals for the future.

4.2 Market Forces

The OECD report noted that the use of taxes and subsidies should lead market forces to embrace recycling. By-products will then compete with conventional products under normal market conditions. The extent of taxes and subsidies used will depend on the particular country, but these should typically reflect the benefits that could accrue to the community if recycling took place.

The amount of recycling should then increase, once there is enough information on the long-term performance and quality of recycled products.

4.3 Leadership

The OECD investigation showed that governments have provided the leadership for increasing recycling and reusing demolition and construction by-products. Forced, by and large, by public opinion and social pressure, governments have tried to develop a system of laws and regulations to restrict the ways in which the construction industry deals with wastes and to encourage the use of recycled products. The report suggested that local authorities could draw their own policy lines, operating in a framework set by national governments or the international community. However, the industry and all interested parties must have an input for the new measures to be implemented successfully.

4.4 Promotion

The OECD report outlined some broad themes which can be used to promote the use of recycled materials. These themes address the three "E's" which are considered to affect the implementation of recycling programmes:

- engineering considerations,
- environmental factors,
- economic feasibility.

Goals can be set for each aspect of the recycling programme, which can include:

- regulations based on legislation, by way of an action plan, to help initiate and stimulate use, guide reuse and address environmental considerations,
- financial incentives and disincentives, by way of fees and taxes, to help stimulate all aspects of recycling,
- developing and transferring knowledge, by initiating and subsidising research and demonstration projects to develop new technologies and standards,
- specifications, new and modified, so that by-products can be specified correctly,
- education, to improve public and industry awareness.

The three aspects of legislation and specification, knowledge development and information sharing are detailed below.

4.4.1 Legislation and Specification

The development of government laws and regulations should help initiate the use of recycled products. Taxes and fees or specific incentives to facilitate the use of recycled materials should be developed. Government should also set limits on appropriate pollution or contamination. Contract documents should be reviewed to include the provision of recycling in the tender, and an evaluation process developed for recycled materials.

Practical guidance and co-operation from the producers of recycled materials and road construction companies is essential to the development of specifications. The specifications should ensure that the completed in-place materials provide the requisite level of service and that it is economic.

4.4.2 Developing Knowledge of Recycled Material

Industry needs comprehensive information on each by-product intended for recycling (which could be retained in databases). This information should address quality control, performance and economic considerations.

For quality control, a description and technical data of the recycled material should be obtained. Quality control plans to ensure product consistency should be established, so that if any variations occur they can be assessed for significance within the parameters set.

The long-term performance of the material should be researched to give users greater understanding of its behaviour. Past work on the same or similar materials can also be investigated to determine any differences and establish the reasons for this.

In areas that have abundant good-quality resources, the recycling of material may not be so economic. Each area's potential will need to be assessed to determine the economics of recycling material there. This will also enable the identification of the most feasible products for recycling. The combination of product use, technical processes and cost should be addressed when considering recycling processes.

4.4.3 Information Sharing

The OECD report recommends that, to help spread the information and initiate awareness, research results and demonstration projects should be published to increase general and specific knowledge of recycled materials. Seminars, workshops and conferences allow interested parties to become more familiar with possible recyclable products and their performance. This information would also help in developing specifications for each by-product.

Typical information may include:

- the characteristics of products,
- roading uses, including research studies,
- experimental use and standard practice,
- risk assessment,
- risk of pollution.

To make the information more accessible, standard terminology that is easy to understand and assess should be used.

5. Current New Zealand Situation

5.1 Current Status of Recycling/Reuse in New Zealand

The recycling of roading materials in New Zealand at present was reviewed, with emphasis on local government, roading contractors, and the central government departments and agencies controlling roading.

In 1998, Transit New Zealand and the various other authorities rehabilitated 535 km and resealed approximately 4800 km of road. Rehabilitation involves the excavation and replacement of asphalt/bitumen/aggregate material. This material can be recycled back into the road, reused as fill, or disposed of at landfills.

In general, recycling practices in New Zealand are well behind those of other countries, especially in Europe, but New Zealand's circumstances are different.

5.2 Local Government

The review sought information from eight typical local authorities on the extent of recycling/reuse of materials into roads, and each council's policy and practices for recycling and other recyclable waste materials. The eight local authorities were:

- Wellington City Council,
- Waitakere City Council,
- Christchurch City Council,
- Gisborne District Council,
- Hastings District Council,
- Masterton District Council,
- Horowhenua District Council,
- Tasman District Council.

Most of the road network in Christchurch, Wellington and Waitakere is sealed. However, Tasman, Gisborne and Hastings also have large distances of unsealed roads.

In the 1997/98 financial year, the largest amount of resealing was done in Wellington, with 11.1% of the roading network being resealed. In the other areas, the average amount of resealing was approximately 5%, although Tasman and Gisborne resealed only about 2.7% of their road networks. Gisborne, however, did the most road rehabilitation: 1.5% of the network. The others ranged from 1% in Masterton to 0.3% in Christchurch. In general, the East Coast areas from Masterton to Gisborne required slightly more rehabilitation, which is probably a reflection of the low bearing capacities of the subgrade materials.

Few local authorities have policies for recycling waste into roads. Wellington City, Waitakere City and Gisborne District are the only authorities among those assessed which have either tried, or conducted feasibility studies into, using recycled materials in road construction.

5.2.1 Wellington

In Wellington City, two processes have been tried for the rehabilitation/recycling of asphalt material. The first used rotomilled asphalt on unsealed roads and involved applying kerosene to soften the bitumen, then rolling to form a pavement, which was then left for three years before resealing. The second process involved heating the asphalt surface to near-liquid state, then patterning the surface or sealing joints between asphalt surfaces. This has been used in some areas where the asphalt pavement was near to requiring rehabilitation. Material was added or removed depending on the need for rehabilitation. This technique is suitable only where there is no deep-seated structural defect in the pavement. Some recycling of the base course and sub-base is done. The current practice requires the material to be stabilised before placement, while excavated material not required is removed to a landfill or used as clean fill.

On-site lime stabilisation of existing pavement gravels was carried out on residential streets from 1989 to 1996. But the practice was stopped because of:

- air pollution and safety issues close to the public and residential properties
- potential damage to underground services.

Wellington City's current policy is to recycle as much asphalt back into the roads as possible. All recently milled material is stockpiled for reuse. The council has not used any waste material in road construction other than asphalt.

In waste management, Wellington City accepts into its landfills each year over 78 000 tonnes of clean fill, 26 000 tonnes of construction and demolition waste, 12 500 tonnes of plastic and 3900 tonnes of glass waste. The quantity of tyre and asphalt waste entering the landfill is not identified.

5.2.2 Waitakere

Waitakere City Council assessed the feasibility of using recycled materials in roads in 1996. The materials developed from this are called Eco-mix, and comprise four main types:

- aggregate made from iron slag,
- aggregate made from steel-making slag,
- rubber,
- plastic (for pothole sealing).

The Eco-mixes were developed mainly for road stabilisation, patch repairs, waterproofing, slurry seals, and hot asphalt mix incorporating plastic.

The only recycled material the council currently uses is steel slag. The processing technique is similar to cold on-site recycling and can be used on asphalt or chipseal pavement. Steel slag, cement and aggregate are placed on the road surface and the material is ploughed into the road, providing a remixed surface. The material is then recompacted using traditional methods, and a couple of sealing coats are applied.

Most rehabilitation of the base course is done using stabilising products, although material removed is reused in non-roading operations.

Waitakere City Council, which also operates a kerbside collection and recycling programme, emphasises the need for partnership with a contractor as a way of sharing the risks inherent in introducing recycling until knowledge is developed. The council has no special provisions promoting the recycling of material into roads, although it has adopted the principles of Agenda 21 (United Nations Earth Summit) in promoting sustainable development.

5.2.3 Others

Masterton, Horowhenua, Tasman and Christchurch seem to have no definitive policy for recycling into roads. Masterton and Horowhenua stabilise the base course in limited amounts with lime or cement, the rest of the excavated material being removed to landfill. For Christchurch City Council, recycling the base course or sub-base is uneconomic, as good quality aggregate can be obtained locally. Christchurch collects kerbside recyclables, which are given to the Recovered Materials Foundation to process. The foundation is currently trialling the recycling of coarse crushed glass, in place of 5 mm aggregate, into footpaths.

Of all the areas studied, Gisborne has the greatest distance of road network and the highest rate of rehabilitation (1.5% in 1997/98). The stabilisation and recycling of the sub-base and base course is regularly carried out, with cement being the dominant form for rehabilitation of aggregate. The use of crushed concrete as sub-base or base course has been considered, but so far nothing has eventuated. Some excavated asphalt is also sold to contractors for use in private pavement construction.

A Transit New Zealand study (Duffin, undated) in the Napier region very successfully trialled a method similar to the cold on-site recycling used by Waitakere. Here cold milling is used for treating surfacing layers on granular pavements that are showing signs of failure, such as flushing. This method has been shown to reduce manpower, resources and time in treating surfacing problems, with potentially significant cost savings. In addition, the accident rate on sections of road treated by cold milling has been reduced.

5.3 Contractors

At the time this review was made in 1999, few contractors in New Zealand used recycled materials in road construction.

The main contractors do not actively use recycled road materials for road construction. Milled asphalt is usually sold to local contractors as poor quality asphalt for use in low-bearing pavements or industrial situations. The main contractors also do not routinely recycle base course and sub-base materials. The material excavated is usually used as fill in other roading and industrial applications, although in some stabilisation works it is reused. Most of the base course and sub-base that requires rehabilitation, or is contaminated, is excavated for disposal at landfills.

In the industry's view, the limited use of recycled asphalt, and possibly other materials, in road construction may be due to the large proportion of New Zealand's roads which are built using chipseal. The main use of asphalt is in the highly trafficked areas in towns and cities, which tends to discourage experimentation. The current economics of recycling also discourage contractors. Factors identified include the cost of regrinding the material using specialist equipment, the relative thinness of asphalt layering, and the limited storage time before bitumen congeals.

However, two companies in New Zealand have developed different methods of recycling asphalt. The first is a recycled asphalt pavement mixture that has been marketed over the past eight years as Eco-mix, which is used for car-parks, driveways and repair work. This Eco-mix uses milled asphalt (usually from the Auckland area), which is crushed and screened, and then blended back into hot-mix asphalt. Eco-mix contains up to 25% recycled asphalt and meets industry standards.

The second method, which is similar to hot on-site recycling, involves "rejuvenation" of asphaltic concrete. An infrared heat source is used to heat the top 20 mm of surface, and then asphalt is added or removed according to requirements. The surface can be imprinted with a pattern. The process has been used in Wellington over the past two years, although it has been used in the US and UK for ten years. The cost is $6–12/m^2$, depending on the area treated, and so far 2000–3000 m^2 of road has been rejuvenated.

However, more contractors are becoming aware of the potential for recycling and are preparing for its use in the industry.

5.4 Central Government

The policy of government departments and agencies towards promoting the recycling of waste materials into roads was reviewed, focusing on the agencies which are directly involved in formulating transportation or environmental policy.

The legislation setting the framework in which the recycling of roading and non-roading materials can take place is the Resource Management Act 1991 (RMA), the basic principle of which is the sustainable management of natural and physical resources. Sustainable management is summarised as managing the use of, and the protection of, natural and physical resources. State highways and associated structures are considered "physical resources".

The production of waste, and its effect on people, the economy and the environment, are matters of concern in New Zealand. The RMA provides a framework for dealing with the management of wastes. The MfE has established New Zealand's Waste Management Policy (www.mfe.govt.nz/issues/waste/Waste_new2.htm#p5_0), which is to:

- ensure that, as far as practicable, New Zealand's waste generators meet the costs of the waste they produce, and
- encourage the implementation of the internationally recognised hierarchy of reduction, reuse, recycling, recovery and residual management by all involved in waste generation and management in New Zealand.

5.4.1 Transportation Policy

The National Land Transport Strategy prepared by the Ministry of Transport (www.transport.govt.nz/html/14docs/14_22doc.shtml) outlines the government's goals in relation to land transport in New Zealand and associated policy objectives. By its nature, this is a high-level document which does not directly address recycling of materials. However, Transit New Zealand (Transit) and Transfund New Zealand (Transfund) have both produced policies which reflect the Transport Strategy and which make some reference to recycling.

In 1999, Transit published its *Planning Policy Manual* (Transit 1999) which included both environmental and construction objectives. The policy describes best practice measures to control or limit the impacts on the environment and the protection of the highway from adverse effects from adjacent land uses. The methods Transit has specified for achieving this policy objective include "specifying greater use of recycled materials in state highway construction and maintenance work". The current maintenance contract includes considering the use of RAP.

Transfund's environmental effects objective (Transfund 1999) is "to mitigate the adverse impacts of the roading infrastructure and construction on the environment" by:

- better understanding of the impact of roading infrastructure and construction on the environment,
- determining acceptable levels of environmental impact (setting environmental baselines/indicators),
- developing cost-effective recycling/reuse techniques.

Transfund has over the years commissioned research into the potential use of waste materials in roading construction. Most of this work has been carried out by Opus Central Laboratories. Two recent research projects commissioned by Transfund were the use of tyre rubber (Patrick & Logan 1996) and the use of waste oil distillation bottoms (Herrington et al. 1993a).

5.5 Contract Processes

This review, and discussion with roading consultants who administer maintenance contracts, indicates that the structural process for developing contracts impedes recycling. Generally, there is no framework that encourages recycling to occur. In addition, uncertainty about the long-term properties of recycled materials has discouraged industry from recycling materials outside a supportive framework.

The processes of tendering for maintenance work and of project evaluation have been reviewed to identify how far they constrain the use of recycled materials. Salient documents are Transfund's *Manual of Competitive Pricing Procedures, Volume 1* (Transfund 1997a), which includes tender evaluation, and *Project Evaluation Manual* (Transfund 1997b). The influence of the maintenance contract framework was also considered, this being either the traditional approach of single items supplied under methods- or performance-based specifications, long-term performance-specified maintenance contracts, or the shorter-term hybrid contracts.

5.5.1 Where Recycling Is Economic

The first group of recycled materials to consider is those whose use is economic – i.e. there is a price advantage. In a traditional contract, the roading authority (and consultant) will identify specifications with which supplied materials and the finished work shall comply. However, most specifications do not envisage the use or incorporation of recycled materials. The contractor's tender would therefore be non-complying if recycled materials were used, and would need to be offered as an alternative tender. Because this tender should be lower in price, there may be good incentives to accept it.

However, there are also impediments, the main one being risk. The performance of recycled materials, or combinations containing recycled materials, is not fully known. Overseas evidence of 5- to 10-year-old roads is available for some recycled materials, but, in accepting this as evidence, the consultant is accepting some risk that it is perhaps not applicable to New Zealand, or the results may change in the long term. There is no incentive for the consultant to accept this risk, so the alternative tender is not likely to be favoured. Because contractors understand this situation, there is little or no encouragement for them to offer an alternative tender containing recycled materials, and so such tenders are seldom offered other than by the occasional enthusiast.

The roading authority/consultant could specify in the request-for-tender that recycled materials are to be included. However, the lack of knowledge of long-term durability means that the roading authority is taking on the risk that normal durability may not be achieved. There could also be problems caused by the absence of specifications to cite for compliance.

Local authorities have more flexibility and encouragement to incorporate recycled materials in roads, as they are also responsible for providing adequate areas for waste landfill. However, to attract Transfund subsidy they must work to reasonable standards of construction, so their choice of recycled materials would need to be conservative. Local authorities would have to make a case to Transfund if they were constructing to lower standards so that they could use recycled materials, and may need to provide some top-up funding to reflect the reduced certainty of long-term durability.

The 10-year performance-specified maintenance contracts would appear to be more conducive to the use of recycled materials. Here materials and methods are not specified and it is the on-site performance that is relevant. However, these contracts have performance indicators that must be achieved at the end of the contract period. The certainty of long-term performance is therefore even more critical, as it will be part of the long-term performance measure.

The "hybrid" contracts (five-year contracts being trialled by Transit) also focus on specifying performance rather than methods. These offer an opportunity in the performance score-card to give some emphasis to environmental factors such as recycling. Long-term performance measures are less used in hybrid contracts compared with the 10-year performance-specified maintenance contracts, but there is a need to ensure (usually by modelling) that pavements are managed to achieve 25-year goals.

It must also be realised, however, that performance contracts with "end result" specifications may also discourage the partnering which may be necessary to help promote recycling initially, as the risk could be borne solely by the contractor. This again raises the issue of knowledge of long-term performance so that the modelling of 25-year pavement performance can be achieved.

5.5.2 Where Recycling Is Uneconomic

Where the inclusion of recycled materials results in higher cost, the impediments of the current contractual process seem even greater. The same issues of lack of specifications for recycling, uncertainty of performance and reluctance to take on risk arise in this situation too. There will also be the need for means to identify and allow for off-setting benefits which may accrue to the wider community and which are not already recognised in the pricing process. At present the *Project Evaluation Manual* allows for some environmental benefits to be quantified, and others to be recognised qualitatively. Formal structures do not yet exist for valuing additional community benefits arising from the recycling of materials.

It is uncertain how far allowing for more benefits might increase recycling. The use of more expensive recycled materials will result in less roading being provided. Moreover, the primary justification for roading projects is the benefits of increased safety and reduced travel time and vehicle operating costs. Environmental benefits are included as additional benefits and can increase a project's priority for funding.

The various roading authorities differ in the extent to which they may consider the wider benefits from recycling. For example, Transit is solely a roading authority and would gain little of the wider benefit of incorporating a material such as tyres or waste oil in roading if the end product cost more. By contrast, a local authority is responsible for the wider environment, and is already incurring charges for waste oil and tyre disposal which could off-set using more expensive road materials if these wastes were recycled.

5.5.3 Length of Contract

The impact on recycling of the length of contract awarded can be identified only in general terms.

Road sections that are resealed or reconstructed are typically about 0.3–0.5 km in urban areas (i.e. often the length of the street) and 0.5–2 km in rural areas. These contract lengths are therefore more likely to favour recycling practices where material is removed from the site, processed and returned, with the trucking involved having a significant impact on costs.

The literature indicates that on-site recycling using large recycling trains is economic because of the long distance of road recycled – up to four kilometres per day. In New Zealand, where there is a patchwork of ages and conditions of road surface, such a practice would mean sections of roading being treated ahead of their normal maintenance schedule. Obviously, this could occur in existing budgets only if the recycling was particularly economic, or other roading sections were treated later than their normal maintenance schedule.

5.5.4 Recommendations

To overcome the impediments to recycling identified above, the following are needed:

- specifications which include recycling processes and recycled materials,
- mechanisms to share the risk of uncertainty in the long-term performance of recycled materials,
- procedures in project evaluation which identify and value the wider environmental benefits of recycling materials.

5.6 Recent Developments in Waste Management Policy

The Ministry for the Environment in 2000 published a report (MfE 2000) providing information and advice from the Waste Minimisation and Management Working Group on the establishment of a National Waste Minimisation Strategy for New Zealand, the theme of which is that as a society we should change our attitude to how we view what we now see as waste. Instead, we should seek to identify existing material as a resource.

This report was intended to stimulate discussion and debate to help the development of the strategy, which is expected to be released for public discussion early in 2002. The report is in three main sections.

- "The problem with waste" provides an overview of the problems created by waste generation and disposal.
- "Working Towards Solutions" gives the working group's suggestions for a vision, goal and objectives for a national strategy and begins to identify the actions necessary to achieve them.
- The "feedback" section outlines issues and questions on which the working group has asked for specific feedback.

Four interconnected waste streams are targeted for management:

- solid waste,
- hazardous waste,
- industrial waste,
- sewage sludge, bio-solids and wastewater.

The report is concerned with the waste entering landfills, 17% of which is construction and demolition waste (including material from roading). Guidelines have been developed for the management of landfills: some poorly managed landfills have been closed, and new landfills must meet stricter environmental standards.

The report details possible ways forward and states that changes in our current patterns of production and consumption are clearly needed. Not only changes in outlook, but also new management approaches and skills, will be required. The report also states that the current legislation has not been helpful in providing waste minimisation solutions.

The working group suggests this "vision statement" to guide a National Waste Minimisation Strategy:

> A society that:
> - fully values its environment;
> - does not waste its resources;
> - takes responsibility for its actions.

and recommends these four goals to underpin it:

- sustainable management of our resources by maximising opportunities for waste minimisation;
- protection of the environment and human health from the harmful effects of waste;
- a society committed to waste minimisation;
- an integrated and comprehensive approach to waste minimisation and management.

The report addresses each goal in turn, and suggests actions by both the government and local government to help implement each.

Recycling of roading materials could be a useful contribution to this strategy. Although roading materials are relatively benign in landfills, construction and demolition waste is a significant portion of landfill material. Roads also represent a significant material resource as they are the layered accumulation over about 60 years of the bitumen and aggregates used for roading.

The impact of the development of the National Waste Minimisation Strategy on recycling in roading is unclear at this stage. However, it is likely that, in future, recycling in roading will be done within a community which is being encouraged to make the best use of available resources and recycle where practical. Funding may also be available to undertake trials of recycling methods as part of the support for industry to develop the confidence and knowledge needed to incorporate recycled material in their processes.

6. Developing Recommendations

6.1 Summary of Findings

It has been found that recycling practices in New Zealand are far behind those of other countries, especially in Europe, but New Zealand's circumstances are different.

Although base-course materials are regularly recycled in New Zealand, the recycling of other roading or transport materials in roads is insignificant, and is confined mainly to trials or to lower-grade uses such as car-parks and driveways. From this review, the researchers identified several impediments, as follows.

- Much information is already available, although technical issues still need to be resolved. An extensive literature exists on the recycling of asphaltic concrete, base-course material and products such as tyres and waste oil. However, little literature exists on the recycling of chipseal materials, New Zealand's main method of surfacing roads.
- The roading industry was found to have variable experience in recycling materials. Apart from base-course materials, most members do not undertake recycling. They are aware of other recycling processes but, because of the lack of encouragement, do not apply these and, apart from a few, were generally inexperienced.
- The structure of the contractual process was found to impede recycling considerably. The framework to encourage use of recycled materials is lacking. In addition, uncertainty about the long-term properties of recycled materials discouraged the industry from recycling outside a supportive framework.
- No national strategy on waste currently exists, although one is in preparation. The MfE is developing a National Waste Minimisation Strategy, due for release for public discussion in early 2002.

These impediments were then considered by the Industry Working Group. The issues involved were discussed and draft recommendations were developed on how to deal with them, as described below.

6.2 Should Anything More Be Done?

A key issue is whether anything more should be done to encourage recycling. It can be fairly argued that economics and the market will decide what recycling is practical. At present there is no constraint on the use of recycled materials in roads, only that the framework makes using recycled materials difficult. The economic environment will change over time, as increasing charges for use of landfills will favour recycling. However, unless a framework to encourage recycling is established, the increased landfill charges could lead merely to increased roading costs or illegal dumping of material.

One counter to the economic argument is that market horizons may be much shorter than the life of the roading materials, which are often in place for 40–60 years. As market horizons may be only 5–15 years, there could be some longer-term benefit that is not yet fully recognised by the market. However, road funders and road authorities are limited in how far they can operate outside immediate market prices.

A theme of the MfE discussion document on the National Waste Minimisation Strategy is that as a society we should change our attitudes to how we view what we now see as waste. Instead, we should seek to identify existing material as a resource. A crude estimate of the size of the "roading resource" is that the national road network comprises approximately 4.8 million cubic metres of bitumen, 25 million cubic metres of sealing chip and 170 million cubic metres of base course. The replacement value of this material resource in today's prices is about $5.9 billion. While not all of this is reusable, and a significant proportion will be partly degraded, such an accumulation of about 50 years of roading material is a large resource.

However, any decision to change the status quo will require additional work – e.g. the development of specifications or procedures by roading authorities, and greater efforts by the industry to take up recycling. It may also affect road maintenance prices. The performance of recycled materials is uncertain, and the industry is likely to accommodate this increased uncertainty by a higher price, at least temporarily, until more certainty is established.

In the end it is a value judgement as well as an economic judgement whether to encourage more recycling in roading. Even where recycling may appear marginal, efficiencies developed over time, after the initial encouragement, can make recycling economic. As the 1997 OECD report noted, often it is public attitudes and consequent government legalisation which initiate recycling. Choosing to encourage recycling would bring the New Zealand roading industry more into line with international practice and with practices emerging in other New Zealand sectors.

Those who support recycling argue that the benefits are more than just economic. While there may be economic benefits from lower cost of materials, which will be reflected in road maintenance costs, recycled materials may also provide additional benefits to road users or external benefits to the wider community. These benefits should be identified, and where possible quantified, so that they can be incorporated into project and tender evaluation tools such as the *Project Evaluation Manual*.

6.2.1 Draft Recommendations

1. Road funders, roading authorities and industry should alter their procedures and processes so as to better allow for the use of recycled roading material, provided that cost increases, if any, are minor.

2. Identify and quantify benefits of recycling to the road user or wider community for inclusion in project evaluation processes such as the *Project Evaluation Manual.*

The advice from the roading industry was clear that recycling could and should be economic. Its members believe that a number of materials could be recycled economically now, if the framework was supportive. They also see it as important that the evaluation process considers the wider community benefit.

6.3 Where to Start?

The first priority is to make the contractual process more supportive of recycling. While technical and industry development still needs to be done, much of this could occur if the framework was more supportive. Four measures were recommended, and are commented on below.

6.3.1 Draft Recommendations

1. Construction and materials specifications should be modified so as to enable recycled material to be included. Initially, the extent of recycled material included could be set conservatively until confidence builds.

The revision of these specifications could be staged so that the most obvious ones are done first, e.g. for hot-mix asphalt and base course.

The industry group strongly emphasised the importance of making an early start. The easiest areas to deal with are to allow the use of recycled material in asphalt at 10–20%, and the use of crushed concrete as an aggregate. The group believed that success with recycling in the easy areas would build acceptance and the capability of extending recycling to other areas.

2. Progressively develop specifications for the individual components of roading mixes for components obtained from recycled materials.

This phase should be developed progressively over several years, as such an extensive set of specifications is more appropriate for a mature recycling industry, such as those in the Netherlands and the US. In Australia, NSW and Victoria are starting to develop such specifications, and these could, with modification, be used in New Zealand.

The industry group noted that a specification for aggregate from crushed concrete is needed, especially for use in the Auckland area. Members saw recycling being jeopardised by the use of low-quality products by those lacking experience with recycled materials.

3. Prepare a guideline methodology for use by local authorities to help establish the potential for the recycling of road materials and materials from other waste streams into roading, as part of their developing recycling policies appropriate to their area.

Local authorities are likely to lead the recycling of materials in roading, as they must also deal with the pressures of providing landfills for disposal of road materials and materials from other streams, e.g. demolition waste, tyres and waste oil.

Cost issues will need resolution. Local authorities could choose to recycle even though the roading is more expensive, as the total cost to the community would be less. They would need to work with Transfund to determine whether the additional road cost is funded at the current 50:50 ratio.

The group saw considerable opportunity for contractors to work with local authorities to establish local recycling. There appears to be no difficulty with joint funding by Transfund so long as the justification is appropriately made. The group did not directly address the need for a guideline.

4. Introduce waste minimisation plans for contractors.

Two Australian states require contractors in the construction sector to produce waste minimisation plans that both address how material waste will be minimised and incorporate recycling in their contracts. Such plans would fit well into network maintenance contracts, as they charge the most appropriate group (those who have the skill, innovation and pricing ability) with working out the details of how to increase recycling. The plans do not require the contractor to recycle materials if it is not practical, only to consider whether recycling could be viable and whether they intend to undertake it. Contractors will then price the tender as they consider appropriate. The tender evaluation process may need some adjustment in order to assess these plans.

The industry group did not consider this recommendation in detail, as members believed that a start could be made on recycling some specific materials and the issue of recycling plans addressed later.

6.4 Does the Industry Need Support?

The roading industry is not fully experienced in recycling, but could be supported in taking up recycling processes in three ways. These are discussed below.

6.4.1 Draft Recommendations

1. Assistance in exchanging information about materials and experiences.

Victoria and NSW operate websites for exchanging information about recycling processes, available materials, trial data, etc. A similar website in New Zealand could assist those undertaking recycling. Limitations to its effectiveness may arise from the need for contractors to retain their intellectual property right on how best to recycle some materials, the expected road life that can be achieved, and the level of risk.

2. Holding demonstration trials.

There will be uncertainties about the performance to be obtained and the level of risk associated with recycling materials. Overseas practices will often need some adaptation to the New Zealand setting. Demonstration trials of various recycling technologies and associated monitoring will help identify performance levels, service life and potential risks. Where relevant, these trials should be linked to those in other countries, such as those held by the FHWA, so that a better understanding of relating data from overseas recycling trials to the New Zealand setting can be developed.

It is believed that the MfE will have some funds available to help support trials. This, together with support from roading authorities in sharing the risk, will help industry to develop the confidence it needs to increase recycling.

3. Undertake research to develop appropriate technologies to recycle materials for which recycling knowledge is limited, but which are of special interest to New Zealand.

Although there is extensive literature on recycling some waste streams, on others there is little, e.g. chipseal layers. There will also be some materials which are of special interest to New Zealand. Research will be needed to help industry develop appropriate techniques for recycling these materials. Some research funds are available for this purpose (e.g. from Transfund, Transit, the Foundation for Research, Science and Technology, and the industry), and other sources might arise through the National Waste Minimisation Strategy.

The need for trials to help build confidence has been noted. However, the industry group emphasised that, if the framework was correct and the specifications were "not excluding", the industry itself was very willing to undertake developmental work. The need to share the trialling risk between contractor and roading authority was emphasised.

6.5 Further Draft Recommendations

The industry group emphasised the keen interest in encouraging recycling within the roading industry, and recommended that the following additional work be undertaken to assist it in implementing recycling.

1. Prioritise recyclable materials and recycling techniques according to their ease of implementation.
2. Review existing literature to determine the quantity and qualities of the materials, and develop an implementation plan for each material.
3. Produce an "enabling" document/specification.
4. Develop an industry "means of compliance".

7. Conclusions

In the light of the Industry Working Group's discussion of the researchers' preliminary findings (see Section 6.1), the economic, structural and attitudinal impediments to recycling in New Zealand can be summarised as follows.

1. There is a lack of economic incentive, because landfill charges are still generally moderate, especially for clean fill, and the cost and energy consumption of specialist equipment can be high.
2. Current road maintenance practices result in variable quality of potentially recyclable material along the road.
3. The use of recycled materials is not recognised in many roading specifications, and tenders using recycled materials are usually treated as alternatives, which can disadvantage the contractor.
4. The long-term performance of recycled materials is uncertain. The risk is not shared but is borne by the rate-payer or roading consultant; in rare cases the contractor may also take on the risk.
5. There is a lack of knowledge of and experience with recycling within the roading industry in New Zealand. Other countries' practices need to be adapted to the New Zealand situation, and the lack of knowledge about the performance of New Zealand-specific materials, e.g. chipseals, must be addressed.
6. There is no national programme for promoting recycling in New Zealand, although a National Waste Minimisation Strategy is being developed for release for discussion in early 2002.

8. Final Recommendations

In the light of the discussion by and draft recommendations from the Industry Working Group, the following final recommendations are made.

1. Roading funders and roading authorities should alter their procedures so as to encourage recycling that is economic to take place.
2. The procedures that should be modified first are those which will encourage the recycling of asphalt, crushed concrete and base course.
3. The benefits of recycling to the road user and wider community should be quantified and included in evaluation procedures.
4. An industry plan should be prepared which prioritises materials for recycling, develops an implementation strategy for each type of material and identifies the needs for demonstration trials and further research.
5. Roading funders and roading authorities should further examine their procedures once the National Waste Minimisation Strategy has been developed to identify the need for any further changes to procedures, such as guideline methodologies, or waste minimisation plans prepared by the contractor.

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"Ecorecycle" <www.ecorecycle.vic.gov.au>

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