Creating what matters for future generations

Guidelines for supply and use of recycled materials

Vivienne Ivory PhD

and

Steve Bagshaw PhD

WSP Research and Innovation Centre

33 The Esplanade

Petone

New Zealand

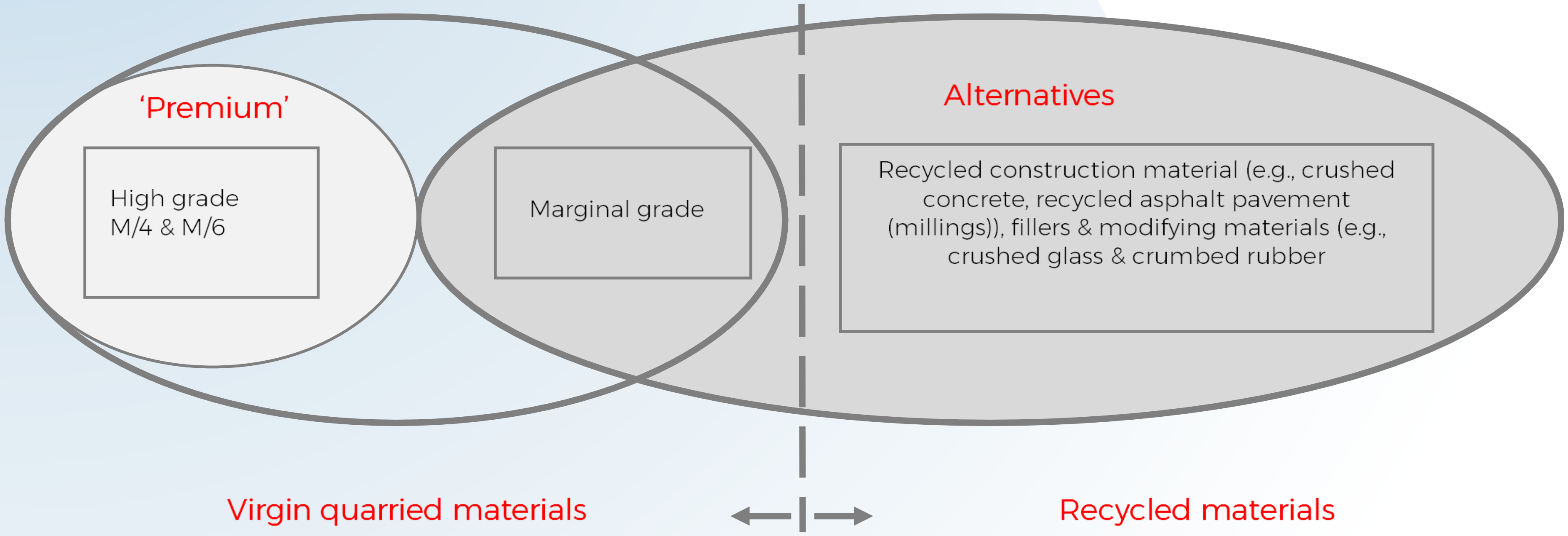
Guidelines for supply and use of recycled materials

Summary of international experience

Recommendations for development of NZ guidelines

How can guidelines contribute to improving the situation

Types of aggregate



All of the above are currently specified for in NZTA M/3 and M/4 specifications

New Zealand has a growing problem with aggregate supply and use

Desired outcomes:

- Sustainable use of virgin aggregates
- Increased use of recycled aggregates
- Guidelines to facilitate their use

United Kingdom

www.wrap.org.uk

wrap

Media Centre | Tenders | Funding | News

Home | Our plan | About us | Sector focus | Taking action

Our vision

WRAP's vision is a world in which resources are used sustainably.

WRAP works with governments, businesses and communities to deliver practical solutions to improve resource efficiency.

Our mission is to accelerate the move to a sustainable, resource-efficient economy by:

- re-inventing how we design, produce and sell products,
- re-thinking how we use and consume products, and
- re-defining what is possible through re-use and recycling

WRAP = Waste and Resources Action Programme

SANRAL = South African National Roads Agency

SAPEM = South African Pavements Engineering Manual

Lessons from international jurisdictions: UK, Sth Africa, Australia, New Zealand

UK:
WRAP, WRAP Aggregain,
Linear quarry
No ‘guidelines’ as such
Specifications

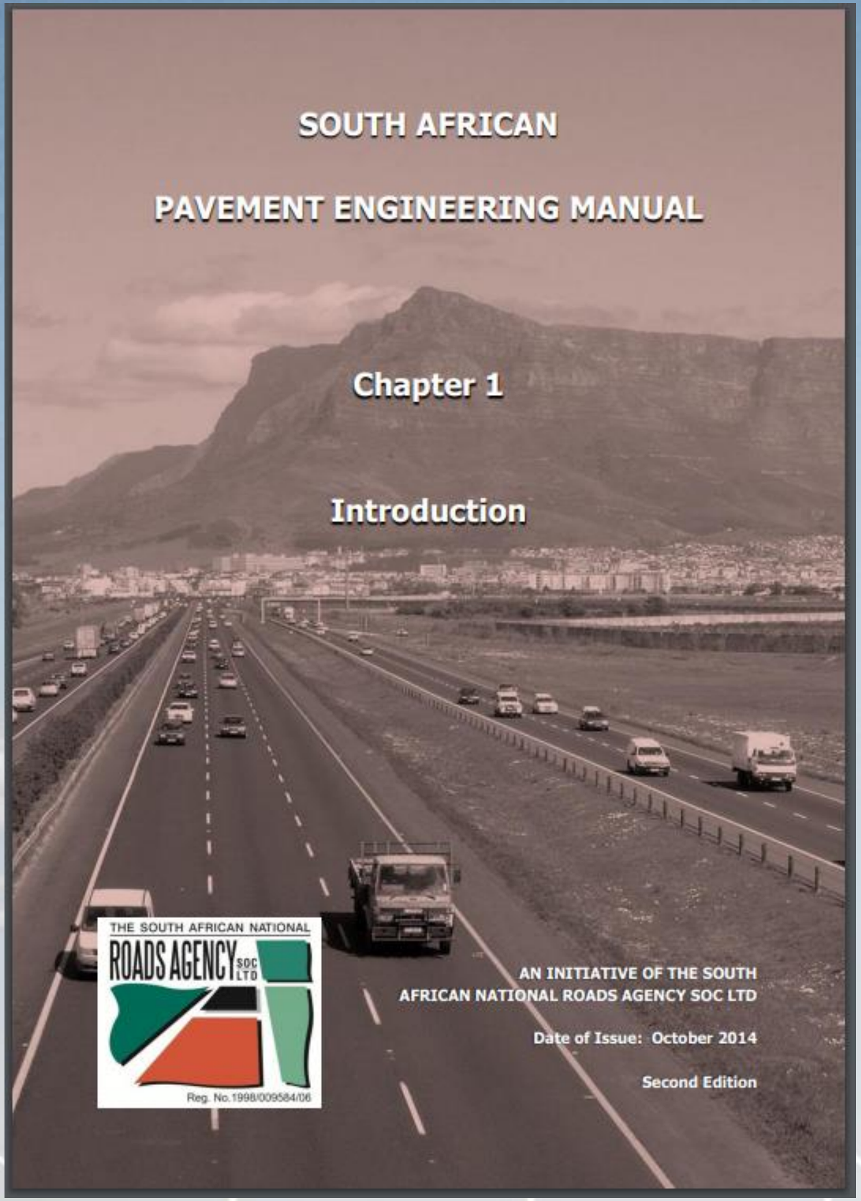
South Africa:
No direct legislation
SANRAL SAPEM identifies recycled materials but poorly developed
Not mentioned by Agrement SA

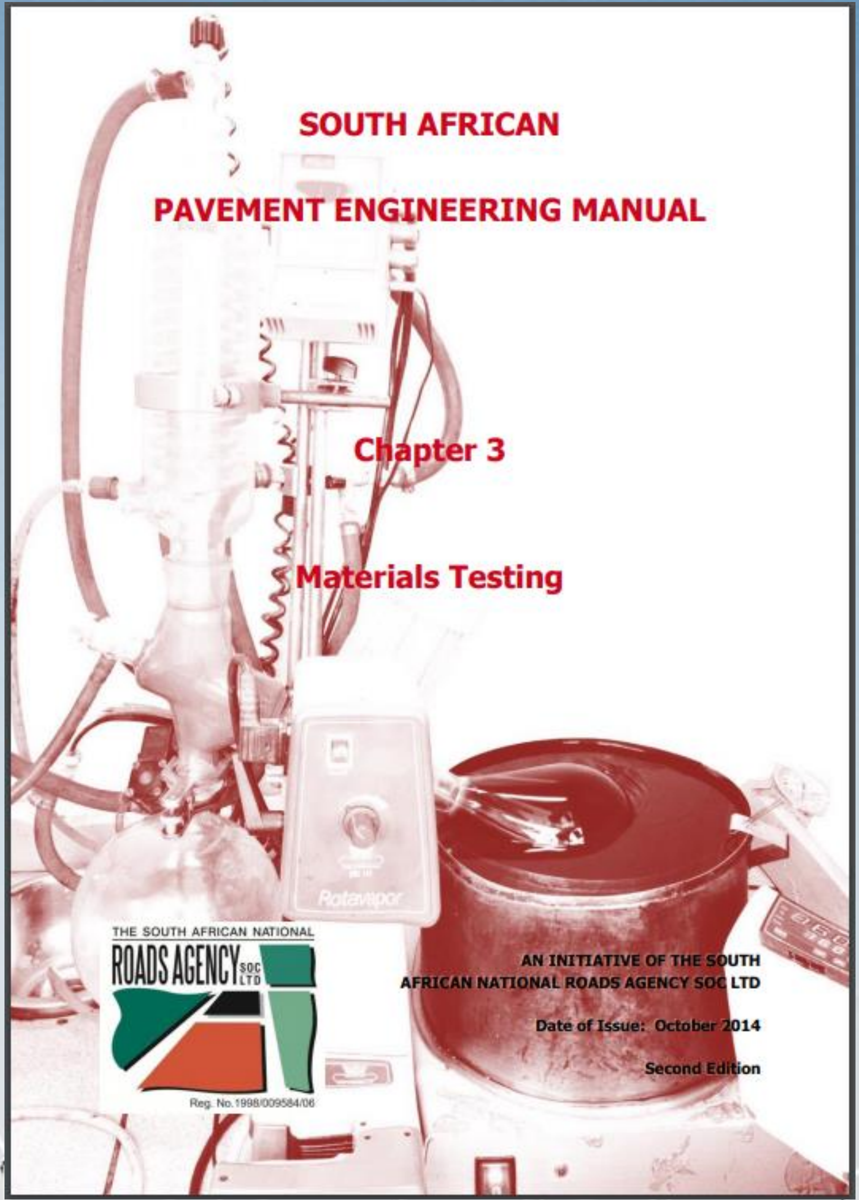
Top-down guidance and legislation
Sustainability focus

Australia:
Strong sustainability push
New specifications
New Best Practice guides
Circular economies

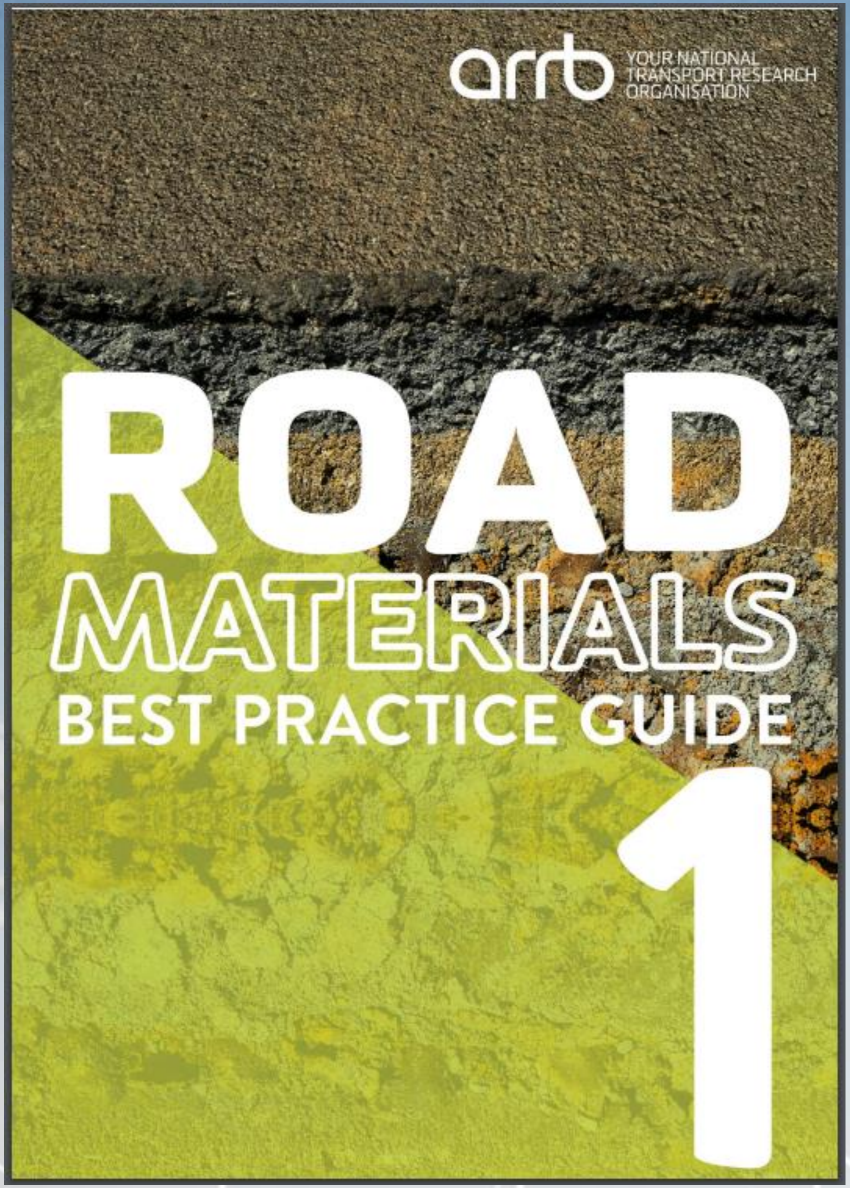
New Zealand:
Currently specified in NZTA specs
No guidelines
Commercial activity
Smaller range of materials

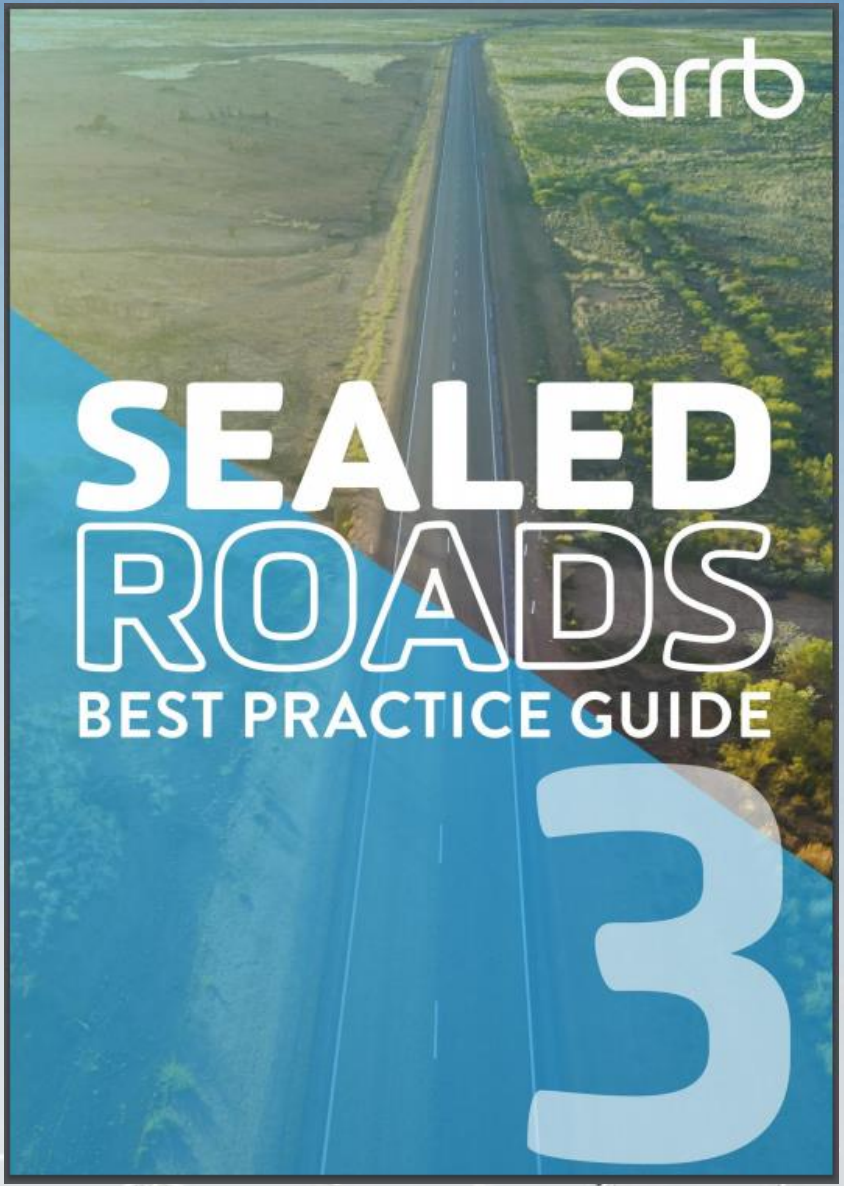
South Africa





Australia


arrb
YOUR NATIONAL TRANSPORT RESEARCH ORGANISATION
ROAD
MATERIALS
BEST PRACTICE GUIDE
1

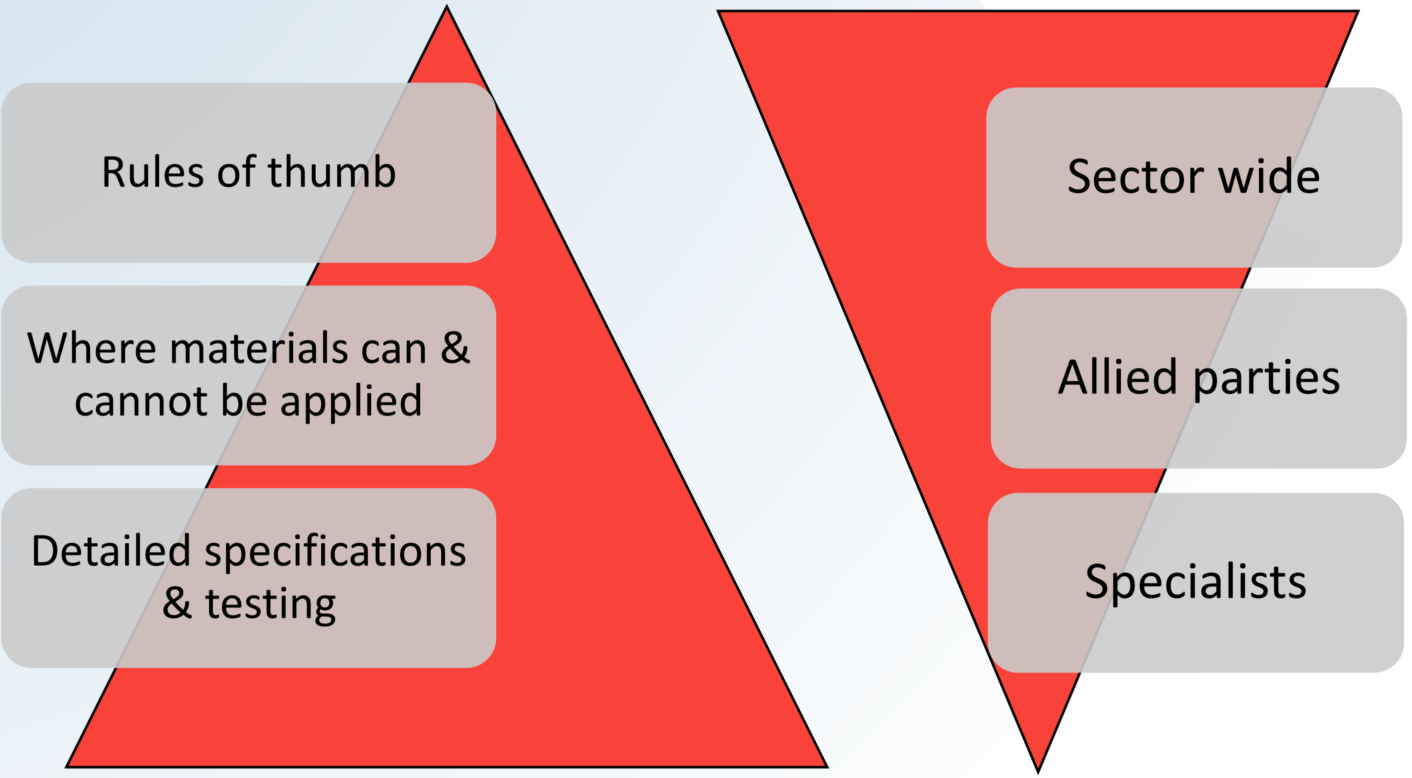

arrb
SEALED
ROADS
BEST PRACTICE GUIDE
3

Hierarchy of information

- Provide multiple levels of information to meet the needs of the whole sector
- Provide easy to find entry points for guideline users and information categories
- Provide sufficiently high level overview for non-specialists to use guidelines
- Provide sufficient depth for specialists to want to use the guidelines

Content & delivery (specificity)
What 'take home' messages will be included?

Used by (coverage):
Who will use the guidelines?
High level info down to specifics



Contents

Why

Sustainable use of aggregates

Why do it?

Holistic reasons for doing it

Economic, environmental, technical, social

Understanding materials

What

Where recycled materials sit in the aggregates portfolio

Different types of recycled/alternative materials

Where could they be used

When could they be used

How

Practical decisions

Sourcing

Source tracing

Source testing

Performance testing

Asset management

Contents

Introduction: 'Why'
Motivation
Education
Information

Match with transport outcomes framework

Provide a 'Mission Statement':

In order to achieve transport outcomes, need greater efficiency in the use of aggregates and greater uptake of alternative materials.

In order to ensure sufficient premium quality aggregate materials remain available for as long and as economically as possible, need increased uptake in the use of recycled and non-premium materials.

1 Introduction

1.1 Background

Local governments fulfil a vital part in the provision and management of Australia's road assets and are responsible for over 80% of the Australian road network. The construction and management of these road assets is challenging considering the significant and diverse assets local governments are responsible for while often being under pressure to obtain better value from their budgets.

The Best Practice Guide for Road Materials is one of a suite of guides developed for local government with the aim of expanding the understanding and capacity to manage road infrastructure. The guides will assist local government and other organisations that manage lower volume roads across Australia to manage their road assets effectively and fulfil their obligations to the community while also improving mobility and safety.

Each guide reflects current global best practice and information and has been tailored to local government requirements.

1.2 Road Materials

The selection and testing of road materials is an integral part of pavement design, construction and ongoing in-service operation. Having a holistic understanding of road materials also provides a roads practitioner with the tools and abilities to produce and maintain a cost-effective, durable asset while maximising sustainable practices and road user safety.

Understanding the various material components of a pavement in addition to the material property requirements are therefore two of the main components of this Guide. This knowledge is supplemented by various tools, techniques and alternatives which can be considered and implemented to reduce costs and increase sustainable outcomes while not jeopardising safety, performance and durability. This holistic materials approach includes:

- use of recycled materials as material alternatives or supplemental additives
- stabilisation methods and appropriate applications to improve material properties and performance
- explanation of formal laboratory test techniques which provide an understanding of a material
- sourcing, extraction and specification of locally available materials to increase the efficiency of sustainable sources
- field quality tests for material construction to ensure a compliant outcome
- fit-for-purpose use of local material including the process of undertaking a material option assessment
- materials used in maintenance and rehabilitation works to prolong the life of current assets.

1.3 Purpose and Scope of the Guide

The purpose of the Guide is to provide local government authorities, state and territory road agencies and other agencies responsible for the management of sealed and unsealed roads with guidelines on ways to manage their road materials, and to achieve both a sustainable and cost-effective outcome.

Throughout the guide, readers are directed to other publications and resources as these documents provide further detailed design and construction information as well as information suitable for the readers' jurisdictions.

New Zealand Context

Link to Transport Outcomes Framework

Link to Climate Change Response Framework

Link to Infrastructure Investment Framework

Link to Environmental Reporting Framework

New Zealand Context

Testing

No additional new tests are required

More testing is generally required to assure quality and performance

‘What’ – ‘Fit for purpose’ materials

Determining ‘fit for purpose’
- do the materials fit the use case, the budget and the risk profile?

Understanding materials
- Understanding type of material, source, source test properties, performance test properties

Risk reduction measures
- Understanding performance measures, understanding case studies

2 Asset Management

2.1 Fit-for-purpose Material Techniques

A fit-for-purpose material has properties and performance characteristics which are directly suited to the chosen design application. The use of a fit-for-purpose material permits budget resources to be optimised over the entire life cycle of the pavement while continuing to meet a required level of service.

Understanding what parameters influence material performance and how to balance this with perhaps use of locally available materials which permit budget optimisation and meet level of service requirements is the key to a fit-for-purpose material.

How a pavement performs either loaded or unloaded throughout the intended design life depends on the following aspects:

- selection and use of appropriate pavement materials
- pavement structural design and drainage
- a construction process and achievement that meets the design intent.

2.1.2 Understanding Loads and Loading Combinations

The performance of a material in a pavement system is determined by the material properties in conjunction with the following external loads:

- traffic loading
- operating moisture environment (and drainage)
- a combination of moisture and traffic.

2.1.3 Understanding the Material

Experience has shown that in many cases practitioners rely on local knowledge when assessing the suitability of various pavement materials in borrow pits rather than obtaining laboratory tests to determine the soil/aggregate properties of materials used. Commonly the lack of material assessments is associated with depletion of local experience and understanding of material properties in addition to unavailability of materials laboratories and consideration of costs.

2.1.4 Reducing Risk

Risk management techniques may reduce the risk of poor pavement performance by altering material properties, controlling moisture, or ensuring good construction and ongoing maintenance practices.

When considering any type of risk management technique an assessment should be made which compares the cost of undertaking the risk management with the expected benefits or reductions in risk caused by applying the chosen method.

‘How’ – Supplying recycled materials

Determining ‘fit for purpose’
- do the materials fit the use case, the budget and the risk profile?

Understanding materials
- Understanding type of material, source, source test properties, performance test properties

Risk reduction measures
- Understanding performance measures, understanding case studies

3.5 Recycled Materials

There are many waste and recycled materials that can be used in road infrastructure. These include:

- reclaimed asphalt pavement (RAP) generally in the form of profilings or slab asphalt which is subsequently crushed and screened
- crushed recycled concrete (CRC) from which steel is removed and the concrete crushed and screened
- construction and demolition waste (C&D)
- crumb rubber mainly sourced from shredding tyres
- glass comingled and crushed
- plastic shredded
- industrial wastes such as slags, fly ash and tailings
- toner.

Recycled materials and asphalt

Blended with the bitumen

- Waste products that can be blended with bitumen include crumb rubber, plastics and filler materials.
- These are expected to give some kind of enhancement to the properties of the resultant asphalt mixture.

Aggregate replacement

- Recycled aggregates can be added to asphalt as a replacement for certain portions of the aggregate particles including recycled crushed glass, some plastics, larger crumb rubber particles, slags and fly ash.
- Typically, these materials are used to replace some of the smaller aggregate particles in the range of 5 mm or below.
- Recycled concrete and C&D waste could be added at larger size ranges in hot mix asphalt but should be limited unless appropriate mix designs are undertaken.

RAP is previously placed HMA which has been removed from a pavement by cold milling or profiling. The removed material may have reached the end of functional life due to age or may have reached a terminal condition through the application of traffic or environmental loads. Some RAP material may also be surplus from asphalt plant production which has been stockpiled.

‘How’ – Making use of recycled materials - Stockpiling

Figure 4.4: Stockpile protection

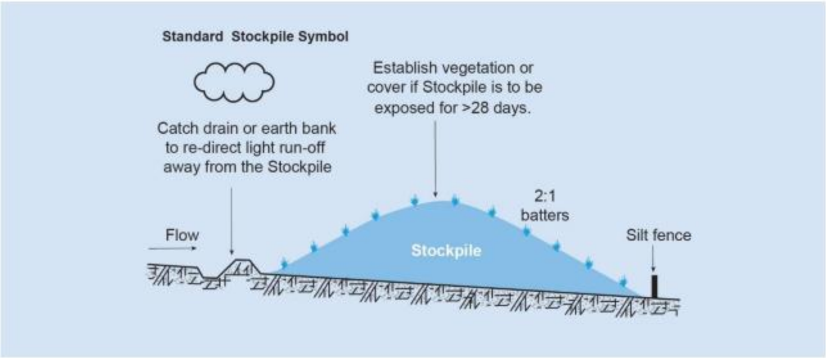
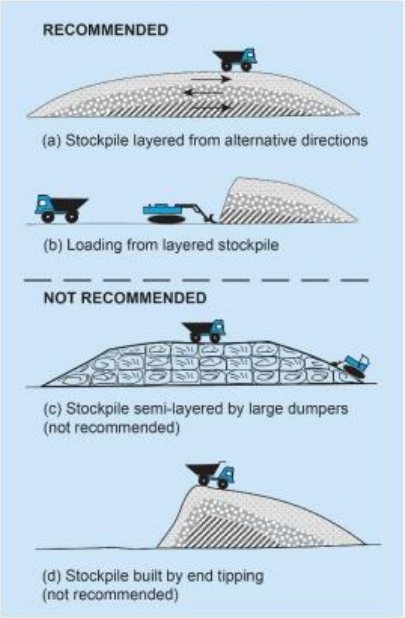


Figure 4.10 illustrates the recommended method to stockpile material and those methods not recommended. The aim is to ensure that in the process of stockpiling and later use the materials are mixed and blended as part of the process so as to minimise later mixing on-site by plant operators.

Figure 4.10: Methods of stockpiling material



Source: *Bartley and Cornwell (1993).*

‘Basic rules’

- Take home messages to improve uptake

Best practice

- Text to describe in greater detail

Best practice

- Images help improve understanding and uptake,
- Text to describe in greater detail

Stockpiles and waste storage sites

Stockpiles and waste storage sites play an important part in road construction and maintenance systems. Stockpiles allow roadwork materials to be stored close to a work site for use during a construction or maintenance operation and allow excess material to be stored for future work. Waste sites allow unwanted material to be collected in one place before removal from the work site. The management of stockpiles and waste storage sites involves consideration of the adverse impact they may have on the surrounding vegetation, waterways and landscape.

Figure 4.3: Stockpile of extracted natural material

Guidelines for the management of stockpiles and waste storage sites include the following:

- Stockpiles and waste storage sites should be located throughout a municipality or region, to allow quick and easy access during roadworks operations.
  - They should be located away from roadsides with significant conservation value and in areas with effective drainage systems.
  - They may be able to be located on cleared private land, after permission is granted from the landholder.
  - Their location should also take into consideration their aesthetic impact on motorists using the road. Location behind roadside vegetation can reduce the visual impact and allow the protection of existing vegetation (Roadside Conservation Committee of Victoria 1995).
- The boundaries of stockpiles and waste storage sites should be clearly marked and fenced to protect surrounding vegetation.
  - Areas for vehicle access and turning should be provided.
- Clean material stored at stockpile and waste storage sites should be kept away from material that is infested with weed seeds or soil-borne pathogens, to prevent cross-contamination.
  - Contaminated material should not be stored near vegetation of significant conservation value, where weed invasion can occur.
- Avoid stockpiling material under trees, as this leads to soil compaction and reduces the effectiveness of surface roots.
- Use weed control measures before stockpiling material.
  - Monitor stockpiles for weed growth and undertake follow-up weed control if necessary.
  - The cleaning of vehicles and machinery before leaving a weed-infested stockpile or waste storage site will help to prevent the spread of weeds.
- The rehabilitation of stockpile and waste storage sites can involve either returning an area to its original condition or converting it into another function that can be used by passing motorists, such as a wayside stop.
  - Rehabilitation to the original condition involves the removal of all non-natural material, deep ripping to reduce soil compaction and replanting of local native vegetation.

One of the most important management measures for stockpiles, whether they be comprised of road materials, topsoil or waste materials, is to protect them from erosion.

Stockpiles can be protected from erosion by applying the following measures (EPA 2004):

- up slope catch drains/banks
- down slope sediment retention structures (e.g. silt fence)
- temporary grassing for stockpiles in place greater than 28 days
- positioning away from drainage lines and at least 10 m from waterways
- covering stockpiles with tarpaulins, geotextile, stabilisation matting or other suitable material
- minimising the number and size of stockpiles
- maximum 2:1 height to width ratio.

Figure 4.4 demonstrates a suitable arrangement for a protected stockpile, including positioning of catch drains, silt fencing and acceptable batter slope gradients.

‘How’ – Making use of recycled materials

‘Rules of thumb’

- Take home messages to improve uptake

Understanding materials

- Images help improve understanding and uptake

Understanding applications

- Understanding performance measures, understanding pros and cons, understanding case studies

RAP rules of thumb

- *Applications*
  - HMA wearing course, basecourse and intermediate course
  - spray seal surfacing aggregate
- ***HMA: under 15% RAP content***
  - direct substitution of aggregate
- ***HMA: over 15% RAP content***
  - requires binder grade adjustments
  - binder blend viscosity design method required

Figure 3.10: Crushed recycled glass cullet and glass sand

3.5.2 Granular Applications

Recycled materials within unbound granular basecourse and subbases are mainly sourced from recovery and/or the reuse of in situ stabilised materials or construction and demolition waste.

Construction and demolition waste consists of:

- primary materials – the main source of stone, making up more than 80% of the product. Examples of this include concrete, which may contain steel reinforcement and brick
- supplementary materials – stone-based materials that are additional to the primary material. These materials can include brick, crushed stone, tiles, masonry and glass
- friable materials – can be tolerated, but if there is too much, they will be detrimental to the product quality and performance. These materials include plaster and clay lumps
- foreign materials – these are detrimental to performance and undesirable, however they cannot be completely eliminated. These can include rubber, paper, plastic, cloth, paint, wood and vegetable matter
- bituminous materials – these can be tolerated in unbound materials (as long as they are not stabilised with cementitious binders). They could be stabilised with the addition of bituminous binders (hot or cold). Examples include asphalt (slabs or profilings) and sprayed seals.
- May contain asbestos which must be managed within the recycling facility.

‘How’ – Making use of recycled materials

Basic starting/entry points

- Describe permitted recycled materials

Materials descriptions

- Describe permitted recycled materials in more detail

Materials descriptions

- Describe permitted recycled materials in more detail

3.5 Recycled Materials

There are many waste and recycled materials that can be used in road infrastructure. These include:

- reclaimed asphalt pavement (RAP) generally in the form of profilings or slab asphalt which is subsequently crushed and screened
- crushed recycled concrete (CRC) from which steel is removed and the concrete crushed and screened
- construction and demolition waste (C&D)
- crumb rubber mainly sourced from shredding tyres
- glass comingled and crushed
- plastic shredded
- industrial wastes such as slags, fly ash and tailings
- toner.

Reclaimed asphalt pavement (RAP)

Large proportions of reclaimed asphalt are recycled back into pavement applications. It is estimated that in Australia about half of all reclaimed asphalt pavement (RAP) is re-used in hot mix asphalt applications. Most of the remainder is used in base or subbase materials, with a small amount being used in cold recycling or as fill.

The main use of RAP is as a component in the manufacture of new hotmix asphalt. Other processes that incorporate the use of RAP include:

- in situ hot asphalt (hot in place asphalt recycling (HIPAR)
- in situ cold asphalt recycling
- cold plant (pug mill) mixing of RAP material.

RAP is previously placed HMA which has been removed from a pavement by cold milling or profiling. The removed material may have reached the end of functional life due to age or may have reached a terminal condition through the application of traffic or environmental loads. Some RAP material may also be surplus from asphalt plant production which has been stockpiled.

Once processed, RAP material is used as a substitute for various sizes of the fine and coarse aggregate fraction in a new HMA or for a spray seal.

The amount of RAP material and the type of HMA the RAP material is combined with will influence the properties and stiffness of the new mix.

Recycled plastic

Polymers have been incorporated into asphalt mixes to improve properties and performance. This has typically been done by incorporating polymers to modify bituminous binders. Similarly, recycled polymers may also result in enhanced performance, provided that a rigorous selection of plastic waste and suitable production conditions are used.

Generally, there are two ways to add polymers or recycled plastics into asphalt mix. These are the dry process through which solid particles are added directly into the mix with the aggregate particles and the wet process, where the virgin binder is modified with the plastics.

'How'- testing of materials properties

Grading characteristics such as the fines ratio (also known as dust ratio) and the grading modulus can be calculated using information from the grading results. These characteristics are good for comparing the grading characteristics of materials quickly and can also be used in specifications (see Section 4.1.3). A summary of the fine ratio and grading modulus are presented in Table 3.22.

Table 3.22: Grading characteristics

Property	Calculation	Comments
Fines ratio	$$FR = \frac{P_{0.075}}{P_{0.425}}$$ where FR = fines ratio $P_{0.075}$ = percentage passing 0.075 mm sieve $P_{0.425}$ = percentage passing 0.425 mm sieve	• A good representation of the grading with a focus on the fine material • Fine material influences performance the most • Fines provide suction and cohesive forces • Fines can also cause instability and moisture sensitivity • 0.20–0.65 typically a stable material
Grading modulus	$$GM = \frac{(300 - (P_{2.36} + P_{0.425} + P_{0.075})}{100}$$ where $GM.$ = grading modulus $P_{2.36}$ = percentage passing 2.36 mm sieve $P_{0.425}$ = percentage passing 0.425 mm sieve $P_{0.075}$ percentage passing 0.075 mm sieve	• Entire grading curve represented by a single value • Allows coarser and finer grading envelopes to be compared easily • Values > 1.5 coarse material • Values < 1.5 fine material

Materials properties testing
- Details of tests can be included

Materials properties testing
- Tests for recycled materials are no different to virgin materials except that frequency and detail may need to be increased in order to maintain QA/QC.

3.7 Laboratory Testing

The following section provides a description of laboratory tests which are typical for pavement and subgrade materials. This includes information on the following:

- purpose of the test
- summarised method of testing
- presentation and descriptions of test results

- how the test results influence material performance in a pavement.

Common laboratory tests which are discussed in the following sections are summarised in Table 3.21.

Table 3.21: Laboratory tests and pavement performance

Laboratory test	Material relevance	Performance influence
Grading (PSD)	• All granular materials • HMA and spray sealing aggregates	• Stability • Stiffness • Density/particle packing • Particle interlock
Plasticity/consistency	• All granular materials	• Stability • Cohesion and suction • Moisture sensitivity • Volumetric instability
Moisture content	• All granular materials	• Stability • Cohesion and suction
Density/moisture relationship	• All granular materials	• Stability • Stiffness • Bearing capacity
California bearing ratio (CBR)	• All granular materials	• Bearing capacity
Repeated load triaxial	• All granular materials	• Stiffness • Permanent deformation • Bearing capacity
Unconfined compressive strength (UCS)	• Modified and cemented granular materials	• Stability • Stiffness
Marshal flow	• Hot mix asphalt	• Stiffness
Marshal stability	• Hot mix asphalt	• Stability • Bearing capacity
Aggregate durability	• HMA and spray sealing aggregates	• Strength • Hardness • Toughness • Soundness
Average least dimension (ALD)	• Spray sealing aggregates	• Surfacing durability • Particle shape

‘How’- using recycled materials: Case studies