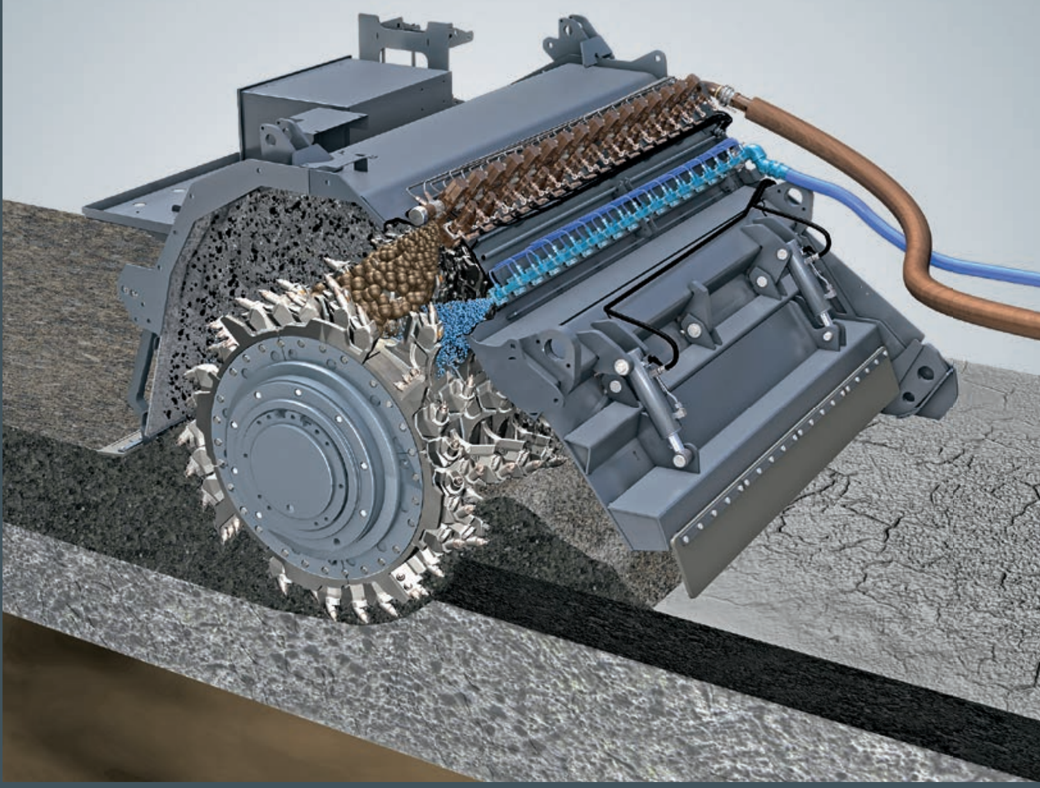
A WIRTGEN GROUP COMPANY

WIRTGEN

Cold Recycling

Wirtgen Cold Recycling Technology



Content

1	Introduction	10
1	Road Pavements	15
1.1	Pavement structures	16
1.2	Pavement components	18
1.2.1	Surfacing	18
1.2.2	Structural layers	19
1.2.3	Subgrade	21
1.3	Primary considerations for the pavement structure	22
1.3.1	Environmental conditions	23
1.3.2	Traffic loading	25
1.4	Pavement distress mechanisms	26
1.4.1	Advanced pavement distress	26
1.5	Pavement maintenance and structural rehabilitation	28
1.6	Rehabilitation options	30
1.6.1	Surface rehabilitation	31
1.6.2	Structural rehabilitation	34
2	Pavement rehabilitation	38
2.1	General	41
2.2	Pavement rehabilitation: investigation and design procedure	42
2.3	STEP 1: Data acquisition / process available information	44
2.3.1	Information on the existing pavement (historical information)	45
2.3.2	Design traffic	46
2.4	STEP 2: Preliminary investigations	48
2.4.1	Determination of uniform sections	49
2.4.2	Visual inspection	52
2.4.3	Reassessment of uniform sections	54
2.5	STEP 3: Detailed investigations	55
2.5.1	Excavating test pits	55
2.5.2	Laboratory testing	56
2.5.3	Extracting core specimens	57

2.5.4	Dynamic cone penetrometer (DCP) probes	58
2.5.5	Analysis of deflection measurements	60
2.5.6	Rut depth measurements	60
2.5.7	Synthesis of all available data	61
2.6	**STEP 4: Preliminary pavement rehabilitation design options**	**62**
2.6.1	Pavement design approach	62
2.6.2	Catalogue design methods	63
2.6.3	Structural number method	63
2.6.4	Pavement number method	64
2.6.5	Mechanistic design methods	66
2.6.6	Deflection based methods	67
2.6.7	Summary of pavement design approaches	67
2.7	**STEP 5: Laboratory mix design**	**68**
2.8	**STEP 6: Finalise pavement design options**	**70**
2.9	**STEP 7: Economic analyses**	**71**
3	Cold recycling	73
3.1	**General**	**75**
3.2	**The cold recycling process**	**77**
3.2.1	In-plant recycling	78
3.2.2	In-place recycling	79
3.3	**In-place recycling machines**	**84**
3.4	**Cold recycling applications**	**90**
3.4.1	100% RAP recycling	93
3.4.2	Blend of RAP / Granular material	94
3.5	**Benefits of cold recycling**	**97**
3.6	**Applicability of the cold recycling process**	**98**
4	Stabilising agents	100
4.1	**Types of stabilisation agents**	**103**
4.1.1	General	103
4.1.2	Material behaviour	104

Content

4.1.3	Cementitious stabilising agents	105
4.1.4	Bitumen stabilising agents	106
4.1.5	Summary of different stabilising agents	109
4.2	**Stabilising with cement**	**110**
4.2.1	General	110
4.2.2	Factors affecting strength	110
4.2.3	Cracking of cement stabilised layers	111
4.2.4	Surface crushing	114
4.2.5	Durability concerns	115
4.2.6	Working with cement	116
4.2.7	Early trafficking	120
4.2.8	Key features of cement stabilised materials	121
4.3	**Stabilising with bitumen**	**123**
4.3.1	Overview	123
4.3.2	BSM Distress Mechanisms	126
4.3.3	Primary determinants of BSM performance	127
4.3.4	Material to be stabilised with bitumen	128
4.3.5	Bitumen stabilising agents	136
4.3.6	Active filler	140
4.3.7	Water quality	141
4.3.8	Mix design procedure	142
4.3.9	Classification of BSMs	144
4.3.10	Working with BSMs	146
4.3.11	Mechanical tests	152
4.3.12	Pavement design approaches for BSMs	154
4.4	**Summary: Advantages and disadvantages of cement and bitumen stabilising agents**	**160**

5 Recycling Solutions 163

5.1	**Guidelines for recycling different pavements**	**165**
5.1.1	Lightly trafficked roads (structural capacity: 0.3 million ESALs)	166
5.1.2	Low volume roads (structural capacity: 1 million ESALs)	168
5.1.3	Secondary rural roads (structural capacity: 3 million ESALs)	170

5.1.4	Main rural roads (structural capacity: 10 million ESALs)	172
5.1.5	Interurban highways (structural capacity: 30 million ESALs)	174
5.1.6	Major multi-lane highways (structural capacity: 100 million ESALs)	176
5.2	**Alternatives for pavement rehabilitation**	**178**
5.2.1	Existing pavement	180
5.2.2	Rehabilitation requirements	181
5.2.3	Rehabilitation options	182
5.2.4	Maintenance requirements	190
5.2.5	Construction & maintenance costs	192
5.2.6	Energy consumption	195
5.2.7	Relevant comments	199

6 Recycling 100% reclaimed asphalt pavement (RAP) material 201

6.1	**RAP material**	**203**
6.1.1	Bitumen binder	203
6.1.2	Grading of the RAP material	205
6.2	**Uses for cold recycled RAP material**	**206**
6.2.1	Untreated RAP material	206
6.2.2	RAP material treated with cement	207
6.2.3	RAP material treated with bitumen emulsion	207
6.2.4	RAP material treated with foamed bitumen	211

Bibliography 214

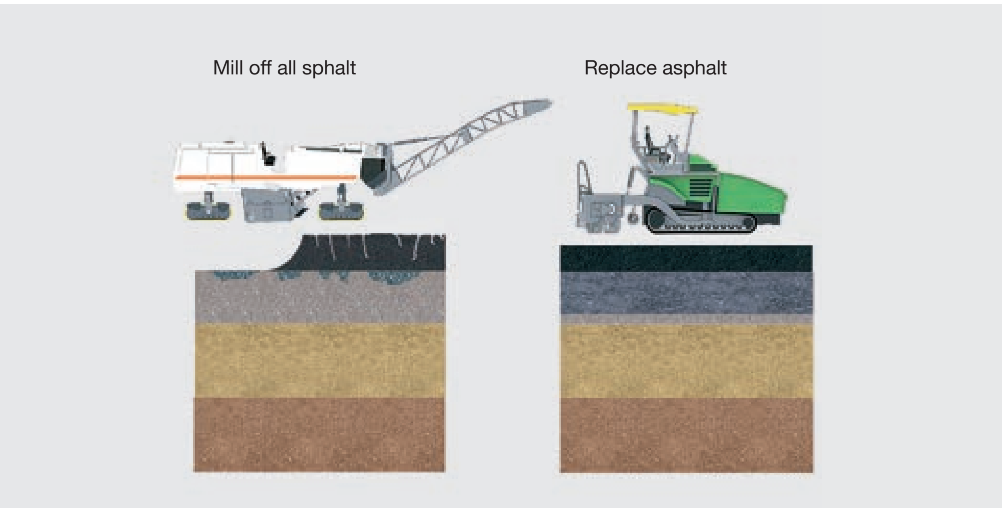
Appendix 1 – Laboratory procedures for stabilised materials (mix designs) 218

Appendix 2 – Determining structural capacity from traffic information 307

Appendix 3 – Guidelines for compiling specifications for recycling projects 320

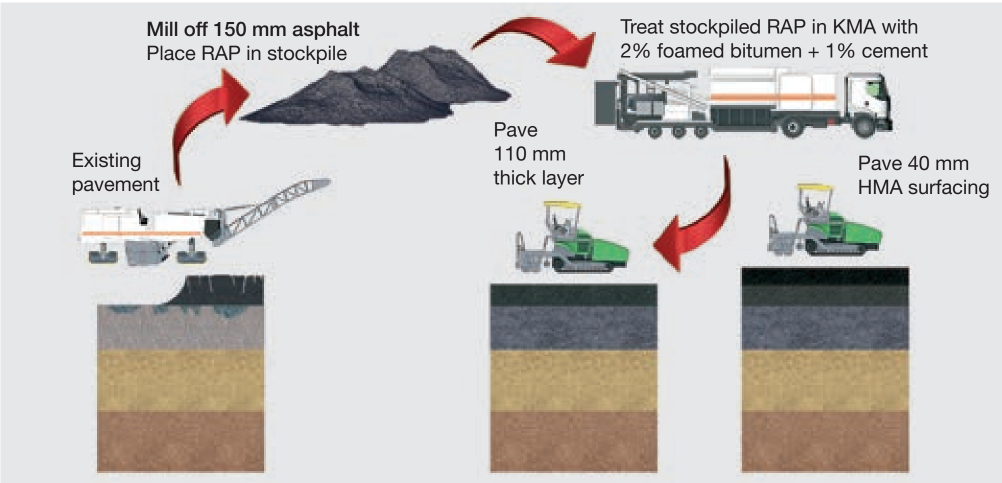
Appendix 4 – The principles of economic analysis 355

> **Mill and replace.** This method removes the offending cracked layer of asphalt and replaces it with fresh hot-mix asphalt, often with a modified binder. The process is relatively fast due to the high production capabilities of modern milling machines. The problem is removed with the layer of asphalt and pavement levels are maintained.

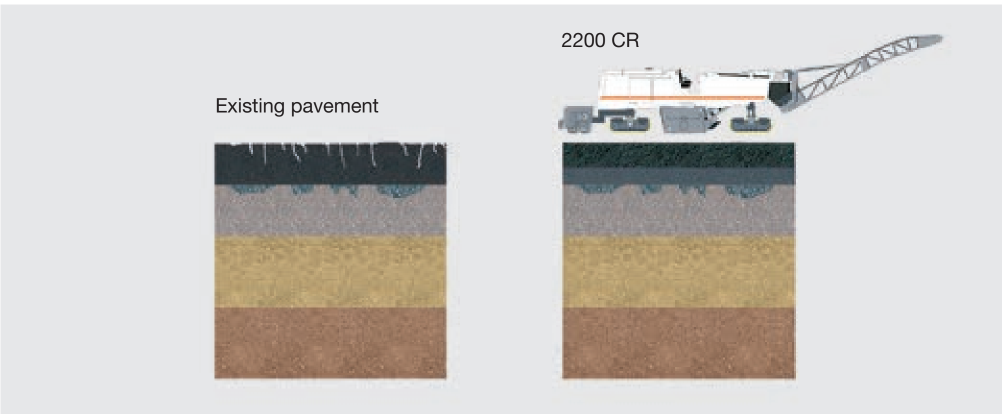


Mill & Replace

> **Recycling** a relatively thin (100 mm – 150 mm) layer of asphalt material from the existing pavement. Such recycling can be done either "in-plant" by transporting milled material to a cold mixing plant KMA 220 or in place by using the 2200 CR or WR 4200.

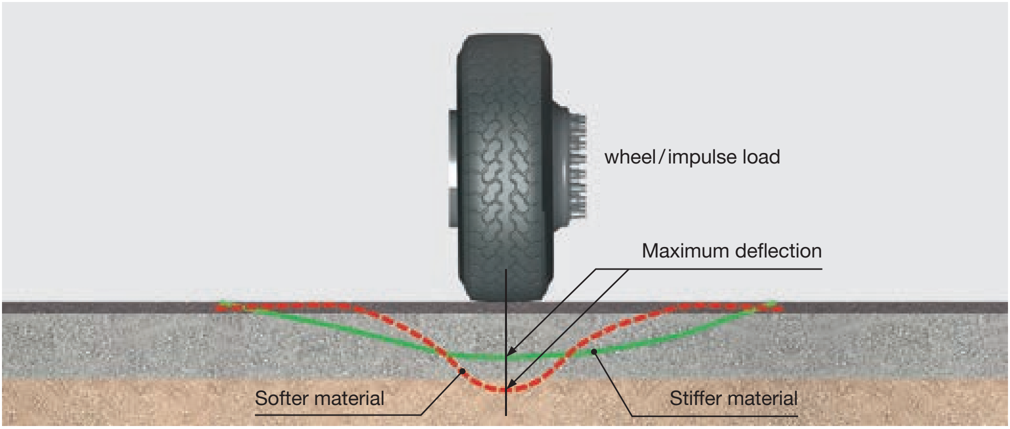


Recycle upper 150 mm



Recycle upper 100 mm

The sketch below illustrates typical deflection bowls measured on two different pavements.



Typical deflection bowls

As primary input for their PMS, road authorities normally carry out deflection surveys at 3 to 5 year intervals on all major roads in their network. Where available, such information is invaluable for the initial definition of uniform sections using simple statistical techniques (cumulative-sum analysis) to identify where changes occur. The cumulative-sum values of maximum deflections are calculated using the formula:

$$S_i = (\delta_i - \delta_{mean}) + S_{i-1} \quad \text{(equation 2.1)}$$

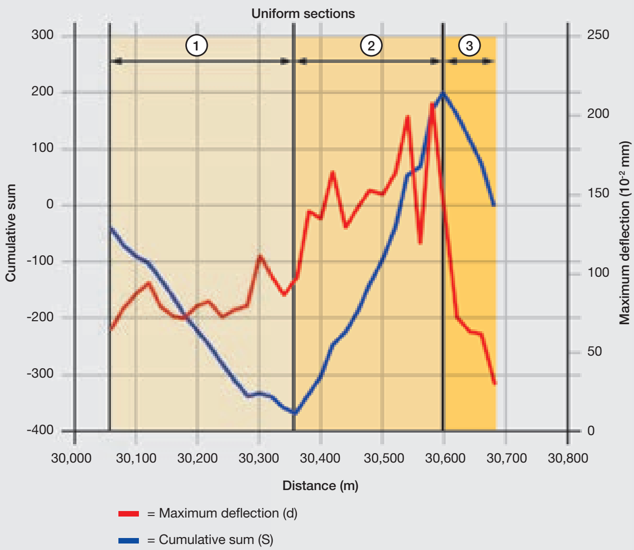
where S_i = cumulative-sum value at location i;
δ_i = maximum deflection at location i; and
δ_{mean} = mean of maximum deflection for the entire section.
S_{i-1} = cumulative-sum value at location before location i

The cumulative-sum value is then plotted at each respective location, normally together with the maximum deflection value plotted on the same graph, as shown in the sketch opposite. A relatively constant slope for the cumulative-sum plot indicates sections of similar pavement response, or a uniform section.

Note: The cumulative-sum method is not restricted to maximum deflection. This method is often used with other deflection indices, such as the Surface Curvature Index (SCI).

Other methods
Where no deflection data is available, uniform sections must be identified by other means. As-built construction information (when available) is often used as an initial guideline, supplemented by a detailed visual assessment, as discussed below. However, when the required structural capacity of the pavement exceeds 10 million ESALs, it is always advisable to undertake a FWD survey at the

Distance (m)	Maximum deflection (d)	Cumulative sum (S)
30,060	64.80	-41.14
30,080	76.70	-70.38
30,100	86.60	-89.71
30,120	94.00	-101.65
30,140	79.10	-128.49
30,160	72.70	-161.73
30,180	71.30	-196.36
30,200	79.50	-222.80
30,220	82.40	-246.34
30,240	71.70	-280.58
30,260	76.80	-309.71
30,280	78.90	-336.75
30,300	110.40	-332.29
30,320	98.70	-339.53
30,340	86.70	-358.76
30,360	97.40	-367.30
30,380	139.60	-333.64
30,400	134.70	-304.88
30,420	164.00	-246.81
30,440	129.50	-223.25
30,460	142.50	-186.69
30,480	152.30	-140.33
30,500	150.10	-96.16
30,520	163.50	-38.60
30,540	198.90	54.36
30,560	119.60	68.02
30,580	208.60	170.69
30,600	132.80	197.55
30,620	72.10	163.71
30,640	63.20	120.98
30,660	61.10	76.14
30,680	29.80	0.00
Mean (D)	105.94	

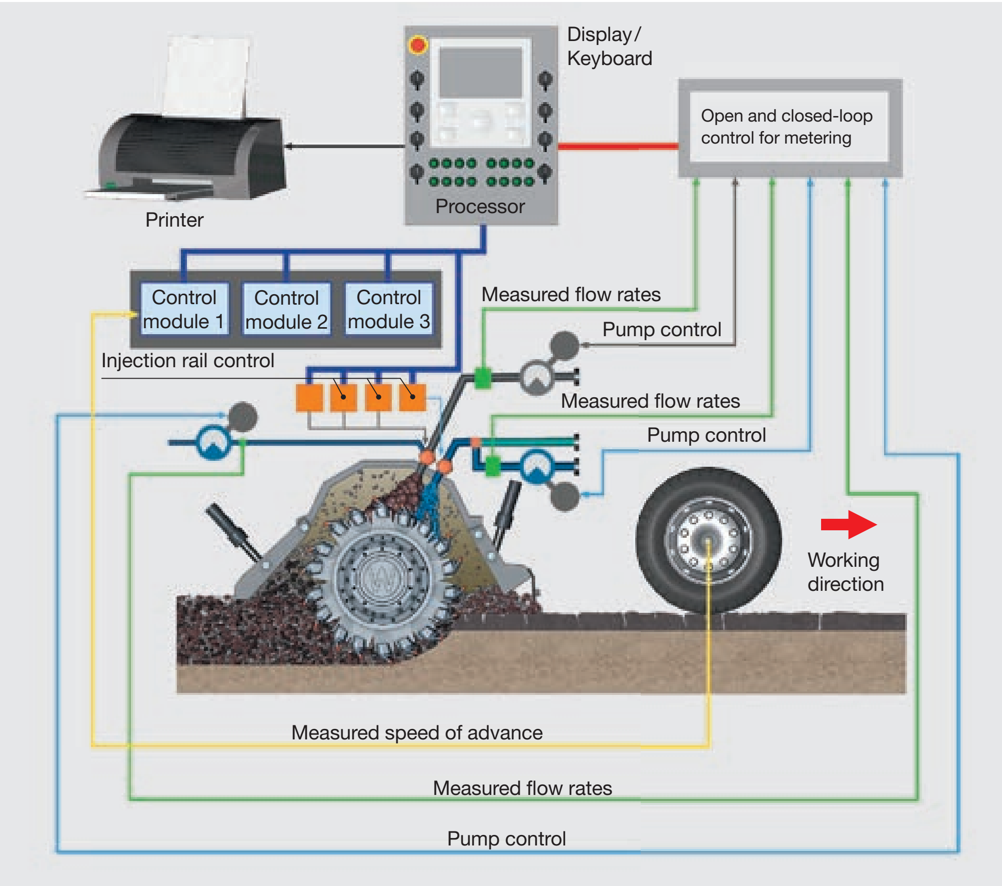


Identification of uniform sections

outset. In addition to identifying uniform sections, the information derived from such a survey is invaluable for the statistical assessment of various in-situ pavement properties (see Section 2.5.5).

Note:

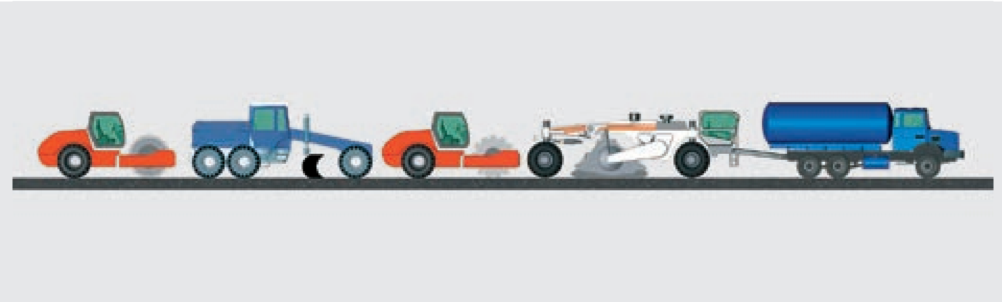
- Cumulative-sum methods can be used to identify uniform sections based on deflection measurements or other relevant information (e.g. subgrade CBR value) collected along the length of the road.



Micro-processor control for the injection systems on the Wirtgen WR 2500 S

Recycling is undertaken by coupling bulk supply tankers to the recycler. The recycler pushes or pulls the tankers supplying the additives required in the mix (e.g. bitumen emulsion).

The combination of tankers coupled to the recycler is configured in accordance with the particular recycling application and the type of stabilising agent that is applied.



Sequency of machine in use

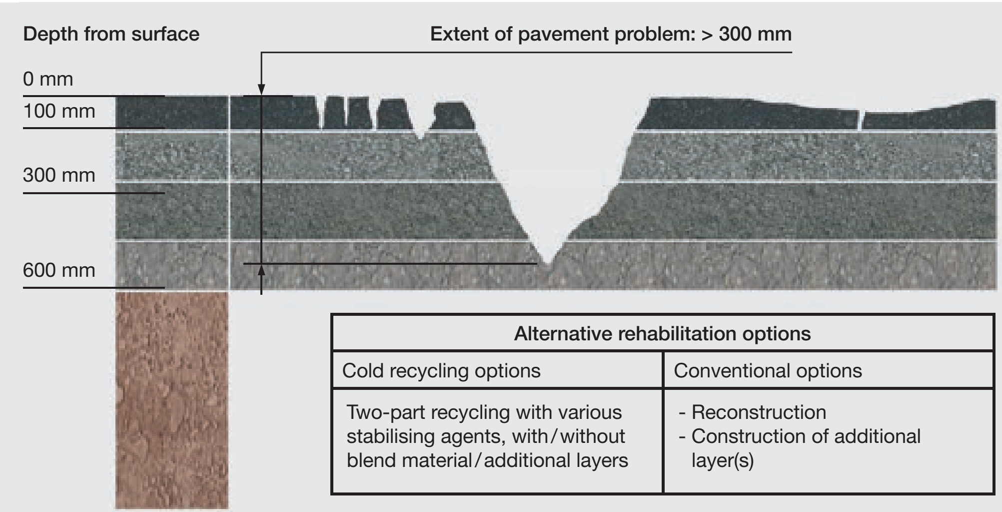
The simplest combination consists of a recycler coupled to a single tanker containing water. As the machine advances, the in situ pavement material is recovered and mixed with water drawn from the tanker. The micro-processor ensures that the required amount of water is injected into the mixing chamber through the spraybar that is mounted on the leading face of the drum housing (illustrated in the sketch on the next page).
The rotating drum mixes the water with the recovered material to achieve a uniform consistency. The rate of water addition is controlled to achieve the moisture content that will allow a high level of density to be achieved when the material is compacted.

As the recycler advances, the mixed material falls back into the void created by the cutting drum and is struck off by a sturdy door fitted to the rear of the drum housing. As shown in the above sketch, a roller follows behind the recycler to compact the material before a grader is used to cut final levels. Not shown in the sketch is the final compaction and finishing process that uses both vibratory and pneumatic-tyred rollers working together with a water tanker.

Powdered stabilising agents (e.g. cement or hydrated lime) are normally spread on the surface of the existing road ahead of the recycling operation. As the recycler advances, the powder is lifted and mixed together with the recovered material and water, all in a single operation.

Note:

- The micro-processor is of paramount importance since it controls the rate of application of water and bitumen



Alternative rehabilitation options	
Cold recycling options	Conventional options
Two-part recycling with various stabilising agents, with/without blend material/additional layers	- Reconstruction - Construction of additional layer(s)

Rehabilitation options for deep-seated structural distress

The materials encountered within the recycling horizon can be classified in to two primary material types:

> 100% reclaimed asphalt pavement (RAP) material where the depth of recycling encounters only asphalt; and

> Blend of RAP/Granular material where the recycling depth includes layers of different materials used to construct the upper portion of the pavement. These include RAP, bituminous surfacing materials, crushed stone and natural gravels, as well as materials that were previously stabilised (mainly crushed stone and natural gravel).

These two material classes are discussed in the following sections together with the different types of treatment that may be considered for improving the engineering properties of the recycled material, where necessary, in order to meet service life expectations of the rehabilitated pavement.

3.4.1 100% RAP recycling

Recycling only RAP material requires consideration of the following factors:

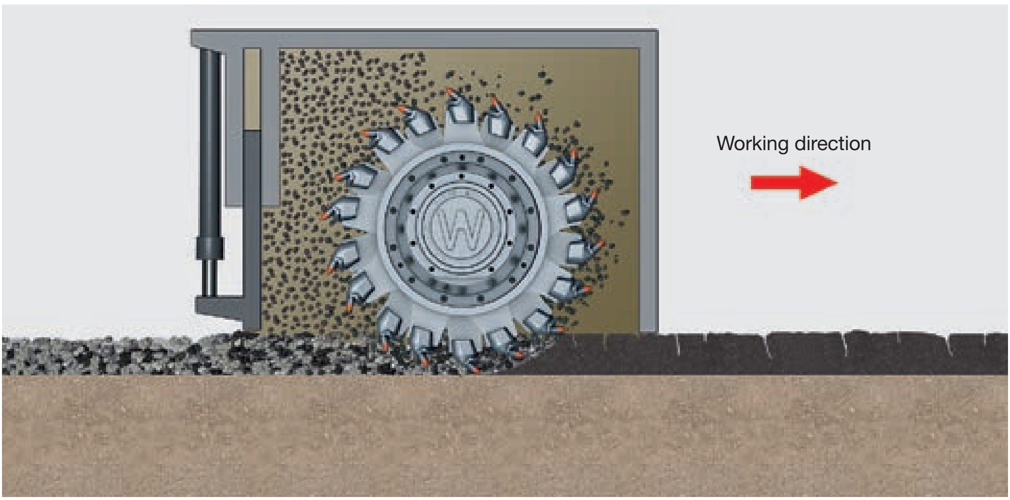
> nature and composition of the existing asphalt (i.e. type of mix, grading of aggregate, binder content, ageing of bitumen, etc.);

> type and cause of distress (i.e. permanent deformation (wheel path rutting / shoving) or cracking (thermal or fatigue mode));

> extent of distress (i.e. isolated or extensive); and

> purpose of recycling (i.e. holding action or restoring structural integrity).

Depending on the structural requirements, the recycled RAP material may be treated with an additive, or returned to the pavement as a granular material (see Chapter 6).



Recycling 100% RAP material