Job Report Cold Recycling

WR 2500 S: Rehabilitation project, Iliki – Athens – Korinthos Highway, Greece

Wirtgen Cold Recycling:

Pavement rehabilitation by recycling with foamed bitumen The Iliki – Athens – Korinthos Highway, Greece

DC Collings, Loudon International, December 2003

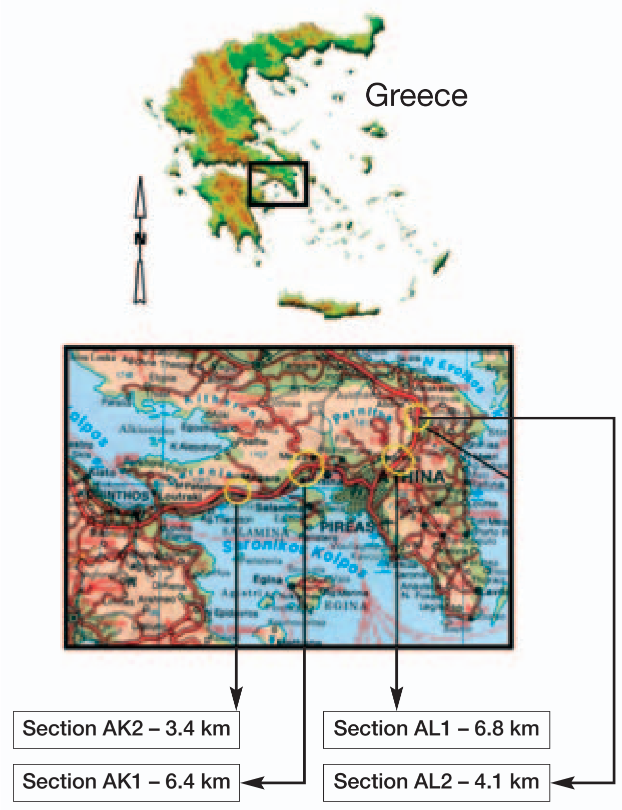
1. Project description

1.1 Background

Following the successful construction of a pilot project on the Athens – Korinthos Highway in 2002, Messrs Aktor were awarded a contract by the Greek national road authority for similar works to be carried out over the entire highway between Iliki, Athens and Korinthos.

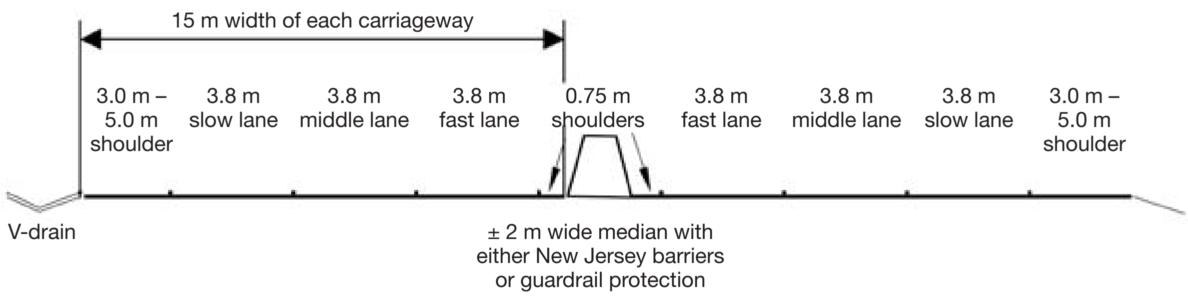
Included in this contract was the rehabilitation of sections by recycling/foamed bitumen stabilisation with Loudon International nominated as engineers responsible for the design.

Four sections, totaling some 21 km of highway (± 600,000 m^2 surface area) were earmarked for rehabilitation by recycling; the remaining ±100 km being strengthened by the construction of additional asphalt layers. Two of the recycling sections lie on the Athens – Iliki highway to the north of Athens, the other two on the Korinthos highway to the west of the city, as shown on the map below. Engineers from Loudon International and Aktor commenced work on field investigations early in July 2003 to determine the optimal design, prior to starting the recycling work two months later, in September.



1.2 The Existing Pavement

To increase the capacity for anticipated traffic growth, the original highway was upgraded to a six-lane dual carriageway facility some ten years ago (as shown in the above cross-section). Traffic volumes during 2003 were in excess of 40,000 vehicles per day, with some 25 % comprising heavy vehicles.



Cross-section of 6-lane dual carriageway

This upgrading required widening each carriageway with new pavement layers. The resulting pavement structure therefore varied across the width, the widened portions generally included a cement-treated base whilst the original construction included both thick asphalt layers as well as graded crushed stone bases.

Extensive distress had occurred, characterised by crocodile cracking and deformation. These failed areas had been repaired by excavating to depths varying from 75 mm to over 300 mm and backfilling with hot-mix asphalt, thereby compounding the non-uniformity of the pavement structure.

Such variability necessitated a relatively intense programme of field investigations, particularly in light of the heavy traffic loading carried by these highways and the structural capacity requirements for the rehabilitated pavement (15 million standard 13-ton axle loads).

2. Field investigations

For the purposes of determining the pavement details and cause of distress, all four sections of highway earmarked for recycling were investigated using the methods described below.

2.1 Falling Weight Deflectometer (FWD) survey

The Department of Transportation Planning and Engineering of the National Technical University of Athens (NTUA) carried out a comprehensive FWD survey during July/August 2003. Deflection measurements were recorded at 100 m intervals along each traffic lane and shoulder (i.e. four measurements per 100 m of each carriageway) using a Dynatest 8002 testing device.

The data acquired from the FWD served two purposes; first to assist in delineating the pavement into uniform sections of equivalent pavement strength and secondly to provide information for analysing in-situ pavement components necessary for structural modelling and evaluation of various rehabilitation strategies.

2.2 Detailed visual assessment

A detailed visual inspection was carried out to record the different forms and severity of distress that where evident in the pavement surface. Simultaneously, other pertinent aspects with regards to drainage, cut/fill conditions, vegetation, surfacing type, etc. were recorded.

Table 1, below, is the visual assessment summary sheet for one of the sections on the Athens – Korinthos highway, indicating that the major area of concern lies in the slow and middle lanes, the most heavily trafficked zone.

Table 1. Summary of Visual Distress

Distress	Cracking			Deformation and Rutting			Patching		
	Sound (%)	Warning (%)	Severe (%)	Sound (%)	Warning (%)	Severe (%)	Sound (%)	Warning (%)	Severe (%)
Criteria (% / unit area)	< 5	5 – 15	> 15	< 5	5 – 15	> 15	< 10	10 – 30	> 30
KA1									
Shoulder	94	6		98	2		92	3	5
Slow	39	19	42	86	8	6	72	17	11
Middle	23	31	46	100			77	16	7
Fast	77	20	3	100			89	6	5
AK1									
Shoulder	92	8		100			100		
Slow	32	34	34	74	13	13	71	10	19
Middle	35	34	31	100			71	11	18
Fast	89	11		100			94	3	3

2.3 Excavation of testpits

At least one testpit was excavated in each uniform section identified from FWD analyses. Additional testpits were also excavated in areas of severe distress as well as areas with little or no distress in an attempt to understand the mechanisms causing distress in the pavement. Test pits were excavated using a Wirtgen W 1000 milling machine to remove the asphalt and layers of cemented base material. A backhoe excavator was then used to remove the underlying materials to a depth of 1 m.

The overall objective of excavating these test pits was to identify the pavement profile. This included:

- individual layer composition;
- the precise thickness of each individual layer;
- in-situ conditions of the materials within the individual component layers; and
- to obtain representative samples from each different layer encountered for laboratory testing, including bulk samples from the upper layers for foamed bitumen mix designs.

Standard soil tests (CBR, Atterberg limits and sieve analysis) were carried out on these samples in order to classify the various materials originally used to construct the pavement.

2.4 Dynamic Cone Penetrometer (DCP) survey

DCP probes were driven on both carriageways at intervals varying between 200 m and 300 m. The number of probes driven at each location varied between two and four, one per lane (including the shoulder), alternating between the inner and outer wheel-paths. The purpose of conducting this survey was to determine the underlying support conditions, the results indicating in-situ bearing strengths/stiffness, as well as consistency.

The field measurements (number of blows/depth of penetration) were reduced using the DCP Analyzer software package, the results revealed a relatively consistent subgrade extending over the entire area of road investigated. These results were used as primary input for the analysis of FWD data (back calculations), thereby improving the confidence of the results thus obtained.

2.5 Core investigation

In addition to excavating testpits, at least ten core holes were drilled per kilometre through both the asphalt and cemented base layers and, where possible, cores recovered.

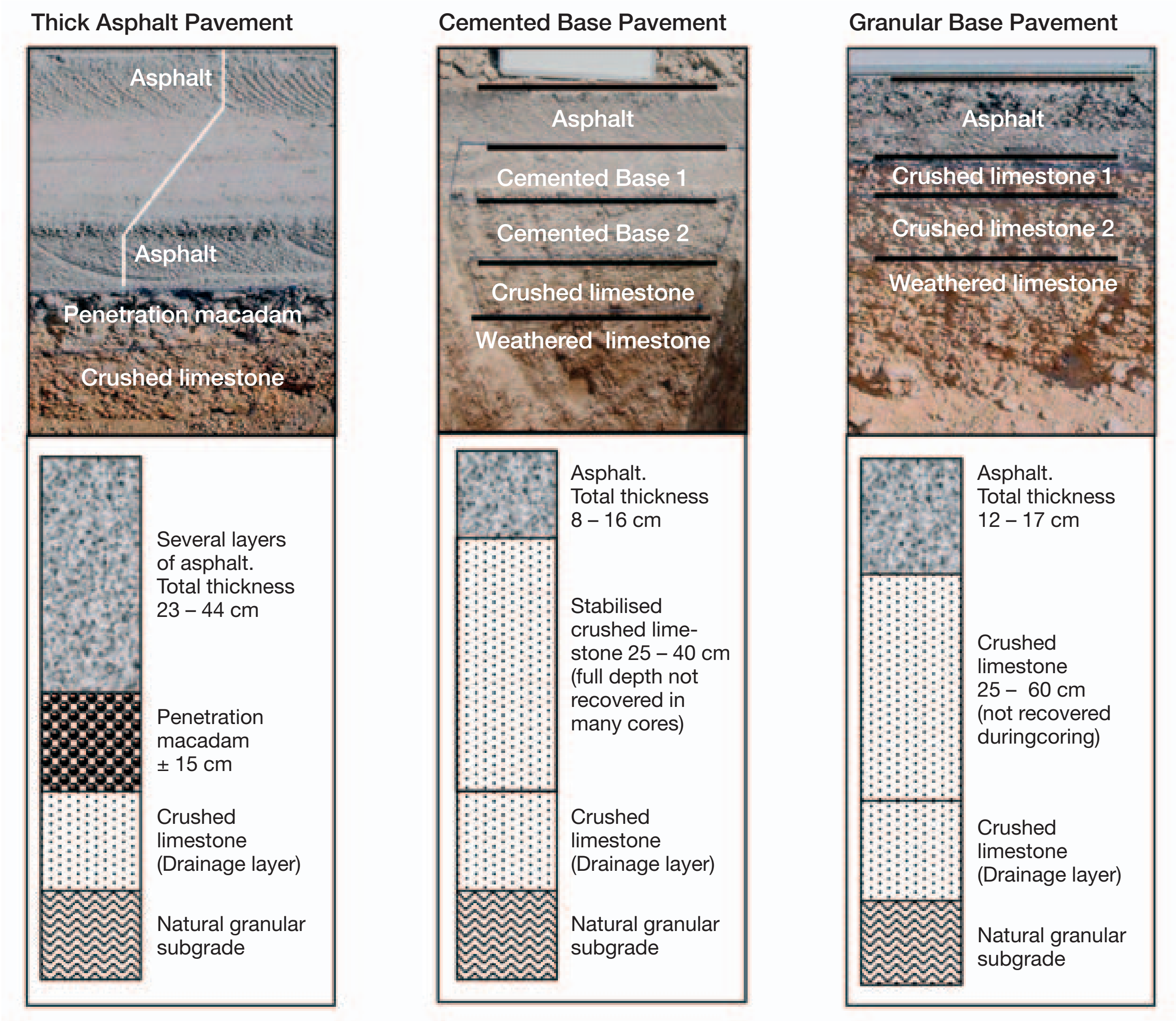
The purpose of extracting these cores was to determine:

- the extent of variation in the different pavement structures identified from testpit excavation;
- the asphalt thickness; and
- where present, the thickness and number of cemented layers in the pavement structure.

The core investigation confirmed the various pavement structures identified from the testpits and provided the information required to identify uniform sections of similar pavement structure. These uniform sections, originally identified from deflection measurements, were thus confirmed or re-defined.

2.6 Summary of pavement investigations

Three different pavement types were determined from the field investigations, as illustrated below:



3. Rehabilitation design

3.1 Design levels

Design surface levels for the rehabilitated pavement were determined by the Greek Road Authority. These levels dictated changes in elevation between the existing and the post-rehabilitation pavement surface, significantly influencing the structural and foamed bitumen design due to:

- variations in the thickness of support remaining beneath the recycled layer. A statistical analysis was carried out to determine the change in level for each uniform section. These were compared with preliminary recycling thickness to determine where the bottom of the recycled layer lay within the existing pavement structure; and
- the ratio of recycled asphalt (RAP) to the underlying cemented or granular material in the stabilised layer.

3.2 Foamed bitumen mix designs

Foamed bitumen mix designs were undertaken to determine the application rates for foamed bitumen and cement to achieve optimal strengths and to determine the strength characteristics for use in the structural design exercise. Such mix designs were performed on seven different blends of material recovered from the test pits. These blends consisted of different percentages of RAP, cemented and/or granular base material, taking into consideration the type of material in the existing base (cemented or granular), existing asphalt thickness, design levels relative to existing surface levels and a preliminary assumed depth for recycling.
The seven blends of material were chosen as representative of the types of material that would result when recycling the various pavement structures determined from the field investigations. These blends were treated with foamed bitumen using the Wirtgen WLB 10 laboratory unit and two different sizes of briquettes manufactured for the purpose of:

- ITS determination using 10 cm diameter Marshall-compacted briquettes. A range of foamed bitumen contents were used to identify optimal application rates that provided the highest ITS value for each blend. This application rate was then adopted for further testing;
- ITS and unconfined compressive strength (UCS) determination using 15 cm diameter (12 cm high) briquettes compacted with 100% of modified Proctor compaction effort; and
- cohesion (c) and angle of internal friction (ϕ) determination from 15 cm diameter (25 cm high) briquettes compacted to approximately 103% of modified Proctor compaction. These values were determined from tri-axial tests.

Table 2. Summary of foamed bitumen mix design tests

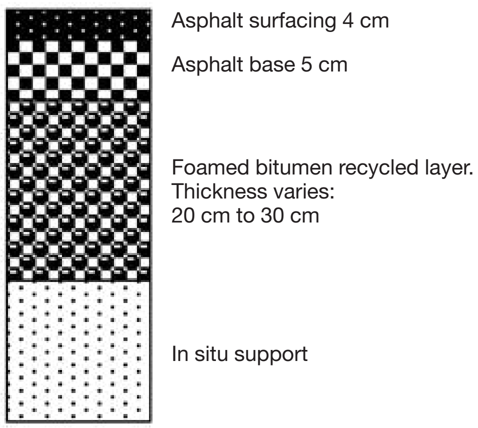
Mix Component					ITS*	ITS*	ITS*	ITS	ITS	ITS	UCS	Tri-axial test	
RAP	CTB	Granular	Bitumen	Cement	dry	wet	retained	equilib	wet	retained		c	ϕ
(%)	(%)	(%)	(%)	(%)	(kPa)	(kPa)	(%)	(kPa)	(kPa)	(%)	(kPa)	(kPa)	(deg)
100			2	1.5	402	441	110	88	90	103	592	214	32.3
75		25	2.5	1	233	216	93	149	169	113	1190	276	35.5
50		25	2.5	1	295	272	92	173	148	86	1198	252	44.7
25		75	2.5	1	445	376	84	168	166	99	2083	319	43.1
75	25		2.5	1	341	349	102	98	90	92	726	174	47.7
50	50		2.5	1	345	322	93	118	88	74	655	136	44.4
25	75		2.5	1	442	452	102	128	105	82	1214	153	53.1

ITS* denotes results of 10 cm diameter briquettes

3.3 Pavement design

Pavement analyses were carried out on the uniform sections using layer moduli determined from a synthesis of FWD deflections, DCP probes and testpit investigations. Statistically determined support characteristics for each uniform section were then used in the pavement design phase.

Recycled Pavement Structure



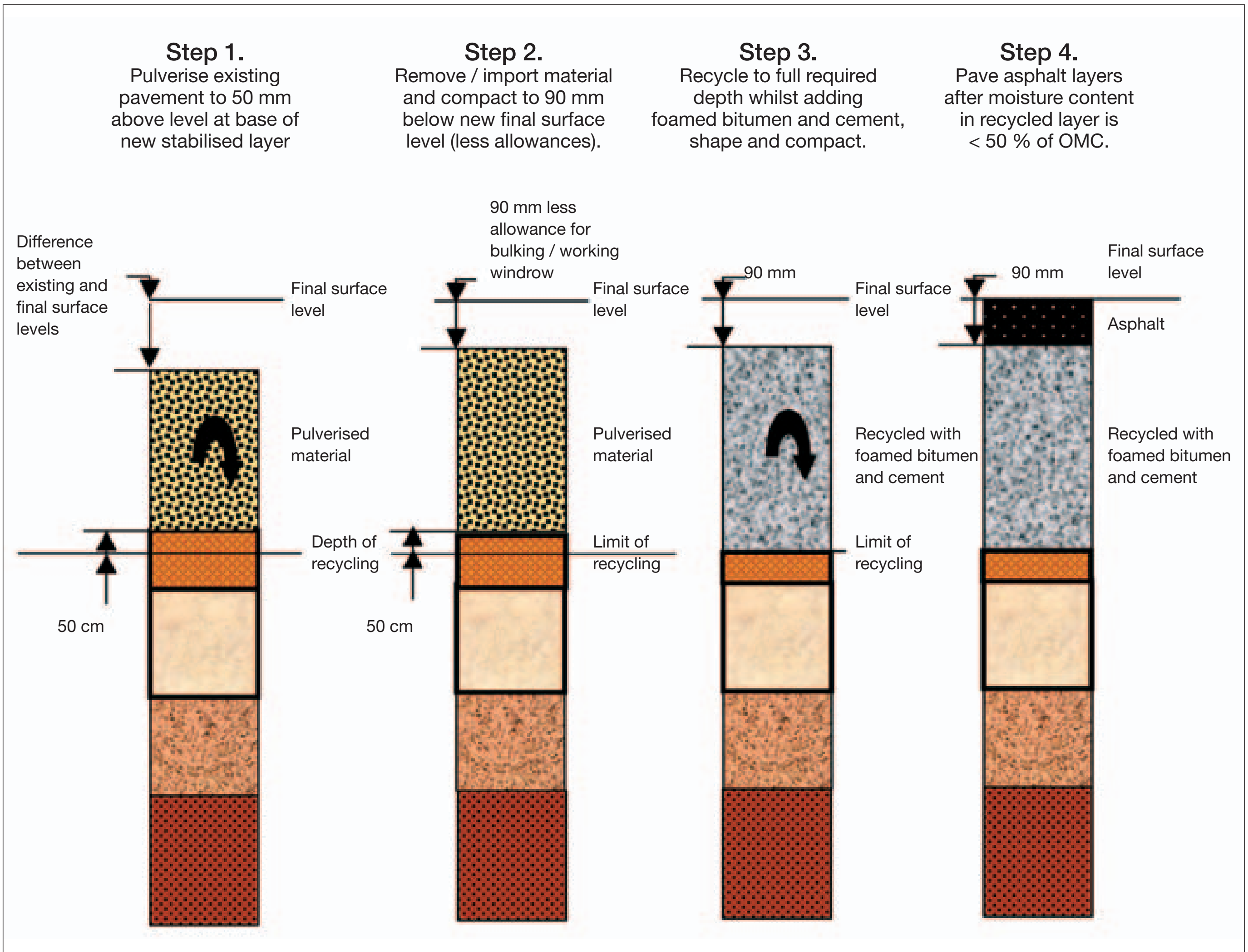
A preliminary rehabilitated pavement structure was assumed consisting of 9 cm asphalt (4 cm surfacing and 5 cm asphalt base) overlying a "standard" 25 cm thick recycled layer on various in situ support conditions (described above).

A mechanistic design approach (based on multi-layer linear-elastic theory, verified by finite element analyses) was adopted to estimate the structural life (capacity) of each pavement configuration. These were then checked utilising advanced modelling techniques based on shear parameters of the recycled material. The results of this exercise were used to adjust the thickness of the recycled layer to meet the structural capacity requirements for each lane on each uniform section. The final designs called for a minimum recycled layer thickness of 20 cm in the fast lane, increasing to a maximum of 30 cm in the heavily trafficked slow lane, dictated by the underlying support conditions and the blend of material to be recycled.

4. Project execution

4.1 Construction sequence

The following sketch illustrates the four-step construction sequence that is described below.

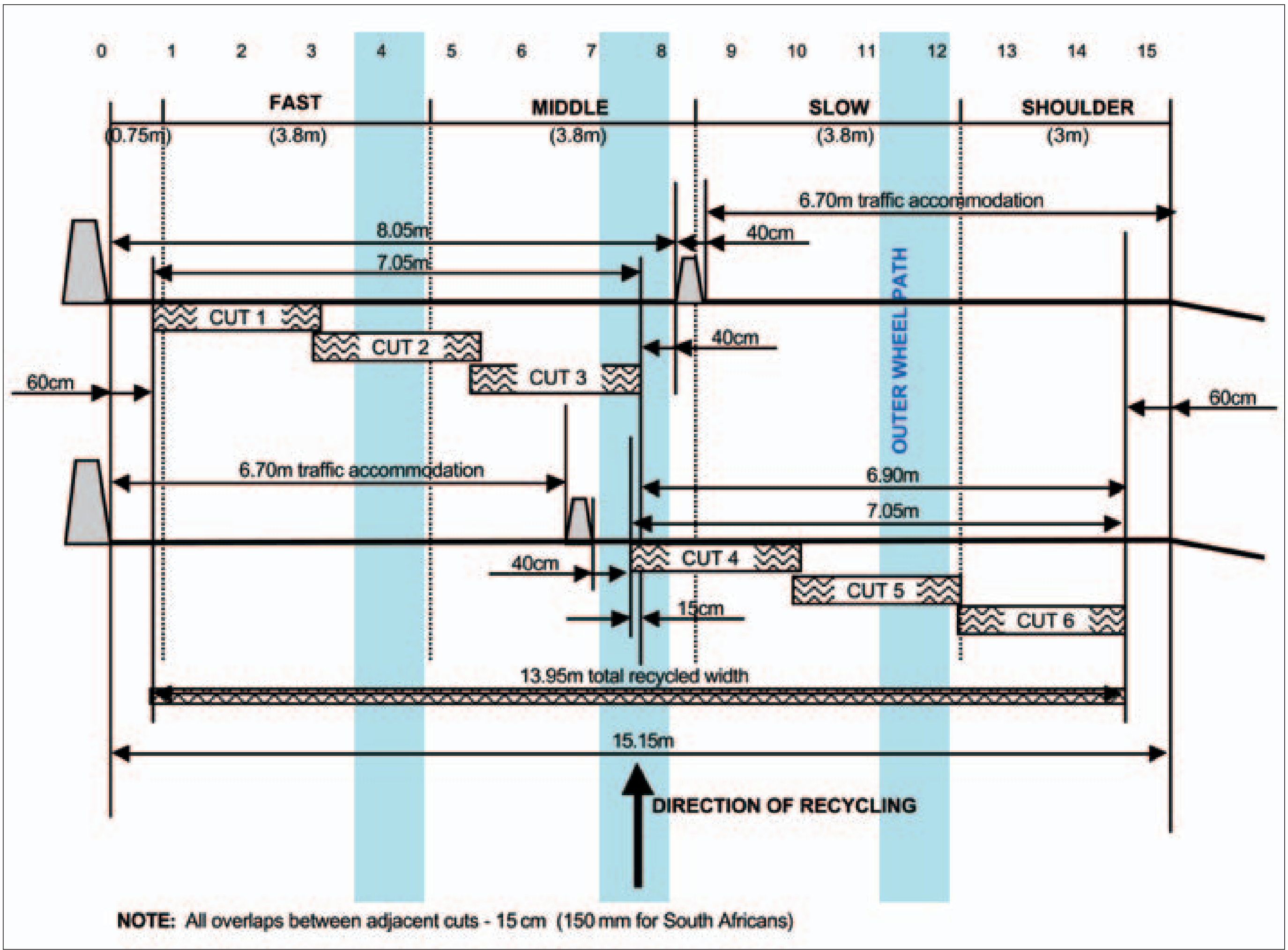


The first "recycling" operation called for the existing pavement to be pulverised by recycling to a predetermined depth. This operation required careful control to ensure that the milling drum remained at least 50 mm above the horizon of the bottom of the new recycled/stabilised layer, thereby maintaining integrity of the existing support.

The pulverised material was then be compacted and shaped in accordance with the new design levels. This resulted in some areas having surplus material that was removed to stockpile. Other areas deficient were made up with material imported from stockpile.

The second "recycling" operation called for the material to be stabilised with a combination of foamed bitumen and cement. The Wirtgen WR 2500 S recycler drew stabilising agents from the Wirtgen WM 1000 cement slurry unit and a bulk bitumen tanker pushed ahead. The material that was recycled included that previously pulverised plus the underlying ± 50 mm of remaining original pavement, thereby achieving the required horizon at the base of the new stabilised layer. This treated material was then compacted to refusal density before final profiling and finishing of the completed layer. The application of the asphalt base was delayed until the moisture content in the upper 100 mm portion of the new recycled layer had reduced to below 50 % of optimum moisture content, normally a period of between 2 and 4 days.

4.2 Cut plan to facilitate traffic accommodation



Each carriageway was treated separately. Requirements stipulated by the Authorities called for a road width of at least 6.5 m to remain open at all times for the accommodation of traffic. Precast concrete barriers were placed as shown on the above cut plan to demarcate the initial working area (the middle and fast lanes) and road marking used to delineate two temporary lanes over the slow lane and shoulder. As soon as the recycling work was complete (cuts 1, 2 and 3) and the asphalt base paved, the barriers were moved to achieve the minimum width requirements for traffic accommodation, temporary road markings painted on the new asphalt and the traffic diverted. Work could then commence on the slow lane and shoulder (cuts 4,5 and 6). Once complete, the 4 cm thick open-graded asphalt surfacing was paved over the full carriageway width and permanent road markings painted.

4.3 Quality assurance

As part of their brief, Loudon International were responsible for establishing and maintaining the necessary quality assurance programmes for monitoring all aspects of the recycling/foamed bitumen stabilising work.

This included:

- Establishing a comprehensive survey control system for level control;
- Ensuring that the required depth of pulverising was achieved;
- Checking that the levels of the compacted/preshaped surface, prior to stabilising, were within the tolerances required to ensure the correct thickness of treatment;
- Monitoring the stabilisation process to achieve the required product; this included:
  - measuring the bitumen temperature prior to connecting tankers to the recycling train;
  - checking the foaming characteristics of every load of bitumen;
  - continuous checks on the depth of recycling relative to the required bottom horizon of the recycled layer;
  - monitoring the recycler's advance speed and other features (e.g. drum rotation speed) that influence the mix quality;
  - taking samples from behind the recycler for briquette manufacture in the site laboratory and subsequent testing to ensure that the required material strengths were achieved;
  - checking the actual consumption of stabilising agents (cement and foamed bitumen) and reconciling with theoretical usage.
- Monitoring the initial compaction undertaken by the 20-ton vibrating padfoot roller by means of a compactometer together with the operating speed, vibration mode and the number of passes applied to each recycled cut;
- Checking that the levels of the completed surface, after cutting by grader, were within the tolerances required to achieve the correct asphalt thickness and riding quality; and
- Checking field densities achieved once all compaction work was complete (smooth-drum vibrating roller and pneumatic-tyred roller).

4.4 Construction activities

The various construction sequences are illustrated in the following series of pictures:

Steps 1 and 2. Preparations for stabilising.

Prepulverising with the Wirtgen WR 2500 S.

Removing surplus material.

Cutting surface levels prior to stabilising.

Step 3. Stabilising, compacting and finishing
The recycling train, consisting of a tanker filled with hot (175 °C) bitumen, a Wirtgen WM 1000 cement slurry mixer (described below), both pushed by the Wirtgen WR 2500 S recycler.

The recycling train.

The Wirtgen WR 2500 S recycler.

The Wirtgen WM 1000 cement slurry mixing unit manufactures up to 1000 litres of cement slurry per minute, drawing from on-board storage facilities. The amount of water added is adjusted to meet the moisture demands of the recycled material. The slurry is pumped to the recycler where it is injected into the milling chamber under pressure through a spraybar separate from the one used to foam bitumen, thereby ensuring the best mix quality possible.

Primary compaction applied immediately behind the recycler by means of a 20-ton vibrating padfoot roller. This roller is fitted with a compactometer that monitors the degree of densification achieved in the recycled layer. Rolling continues until this meter indicates that the maximum density achievable has been obtained (normally between 9 and 15 uni-directional passes). The average density achieved is equivalent to 102 % of modified Proctor density.

Cutting final surface levels by grader after the three adjacent cuts that have been recycled and compacted by padfoot rolling.

Compacting the upper portion of the layer disturbed by cutting levels using a smooth-drum vibrating roller. Water is sprayed on the surface prior to and during compaction, as demanded by ambient conditions.

Finishing to achieve a tightly-knit surface using a pneumatic-tyred roller. Generous applications of water are applied whilst rolling, thereby generating a “slush” to close surface voids.

The completed base. Provided the surface is maintained in a moist state or protected by a light fog spray of diluted emulsion, this base may be trafficked for several days before applying the surfacing.

Step 4. Paving the asphalt layers.

A Vögele Super 1800 paver applies the 50 mm asphalt binder layer, full width.

After compaction and applying temporary road markings, the traffic is moved onto the completed pavement.


The outer half of the carriageway is then recycled.

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