DRAFT ENRICHMENT DESIGN MANUAL

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ABSTRACT

This report takes the form of a draft surface enrichment design manual. It describes the design of enrichment seals to extend the life of old well textured seal coats using dilute bitumen emulsion binder.

CONTENTS

1. INTRODUCTION

Surface enrichments are intended to provide a relatively cheap rehabilitative or corrective treatment to extend the life of existing bituminous surfacings. This type of treatment can be applied in a number of circumstances, however, this draft guide is directed at design of enrichments to be applied to well textured old seals where embedment is complete and the seal binder has deteriorated due to oxidation to the extent that stone loss or cracking is or can be expected to occur.

The publication outlines design theory and a design method including a standard worksheet for enrichments using bitumen emulsion binder. The design method is interim in nature and is expected to be revised in about two years, however it is based on local trials and experience and can be expected to give generally satisfactory results. The guide does not replace Operations Branch Circular No.51 which provides advice on practical aspects of the techniques of surface enrichment.

2. TERMINOLOGY

In general the terminology used in this guide is in accordance with Australian Standard 1348.1-1966 ‘Road and Traffic Engineering. Glossary of Terms Part 1 Road Design and Construction’.

This standard defines a surface enrichment or enrichment seal as ‘A light application of bituminous material, with or without a fine aggregate cover, to increase the binder content of a bituminous surfacing’. In terms of this design guide it is assumed the application of a cover material is omitted.

3. FUNCTIONS OF AN ENRICHMENT

An explanation of the functions of an enrichment requires an understanding of the causes of seal distress. In brief, assuming a seal coat has been correctly designed and applied to a sound pavement and durable cover aggregate was used, the life of such a surfacing is usually dependent on the rate at which the binder hardens through oxidation. Seal failure begins to occur when oxidation results in the bitumen becoming so brittle that fracture can occur under traffic or thermal stresses. Fracture may take the form of failure in the film of binder anchoring the aggregate particles (ie stone loss) or in the layer of bitumen along a line of stress concentration (ie cracking). The problems of oxidation and fracture may be exacerbated by binder absorption into the base or cover aggregate or by the use of a low initial seal binder application rate.

In terms of this design guide, an enrichment is intended to provide a preventative treatment for stone loss and cracking. It should be noted that enrichment treatments are not effective in treating existing cracking except in the very short term, but they can be expected to minimise the formation of further cracks. Properly designed and applied, an enrichment can be expected to extend seal life for at least four years.

4. MATERIALS

4.1 Bitumen Emulsion

The preferred binder for enrichments is cationic rapid setting bitumen emulsion diluted with water in the ratio 4 emulsion : 1 water. The most suitable emulsion for general use is CRS/50 conforming to the requirements of AS 1150 'Bitumen Emulsion for Construction and Maintenance of Pavements'.

Dilution of the emulson is required to reduce viscosity and assist the binder to run off the top of the seal aggregate into the voids. Dilution beyond a ratio of 4:1 does not significantly reduce viscosity but does prolong setting up.

This increases the risk of pick-up problems and should generally be avoided.

4.2 Cutback Bitumen

Although this design guide is based on the use of bitumen emulsions, cutback bituments can be used successfully for enrichment treatments. Apart from environmental concerns, use is complicated by the prolonged setting time involved as evaporation of cutter is progressive and can take weeks. In some circumstances this can create pick-up problems. For these reasons cutback bitumen should only be considered in exceptional circumstances where emulsions are not economically available, traffic densities are very low and the old seal has a high surface texture. Design procedures must be modified according to the cutback blend to be used.

5. DESIGN THEORY AND CONSTRAINTS

5.1 Candidate Surface Selection

Assessment of the suitability of an existing surfacing for enrichment should consider the following factors:

- pavement condition and long term strategy
- seal age
- seal stone loss
- seal cracking
- seal surface texture
- traffic conditions

5.1.1 Pavement Condition and Long Term Strategy

Enrichment treatments should normally only be considered when the pavement is in good condition, however, a variety of circumstances may arise where such a treatment is viable. Each job should be considered on its merits and economic analysis applied to assist in decision making.

An example of such analysis applied to the fairly common situation of a sound pavement which may be considered for a reseal or an enrichment is included in Appendix A. This shows that given the costs and other assumption used, an enrichment life of about four years or more is required for this process to be more economic than a reseal.

5.1.2 Seal Age

The age of an existing surfacing provides a guide as to the likely extent of oxidation of the bitumen binder and hence the surface condition. Typically seal coats in WA last about 16 years but should be examined for signs of deterioration after about 10 years, depending on service conditions.

5.1.3 Seal Stone Loss

The primary aim of an enrichment treatment is to prevent further stone loss from a seal coat. It is preferable to apply an enrichment before stone loss has reached a significant level and caused a loss in serviceability. Typically enrichment should be considered before there is 10% stone loss.

5.1.4 Seal Cracking

Cracking can be a good indicator of binder conditions, however enrichments will not seal cracks for more than one year and in general this type of treatment should not be considered a remedy for existing cracks. Enrichment treatments do minimise further cracking due to binder embrittlement, hence they are a viable treatment for an aged seal provided they are applied while cracking is minimal.

5.1.5 Seal Surface Texture

Enrichment treatments should only be applied to surfaces which have sufficient surface texture to receive the overspray and still retain sufficient texture to provide for adequate skid resistance. The texture required for adequate skid resistance varies according to circumstances as detailed in draft MRD Skid Resistance Guidelines. For typical rural roads values of from 0.6 to 0.8 mm are stipulated. It is suggested that a safety margin be applied to cater for variability within a design unit and a minimum final texture depth of 1.0 mm be used for general design purposes. Where the seal aggregate is smooth and flat and presents a large horizontal surface area, pick-up and skid resistance problems may be exacerbated and extra caution in design and application should be exercised.

5.1.6 Traffic Conditions

Enrichments are applied to the surface of an existing seal, usually without the subsequent application of a cover aggregate. Some binder will remain on the top of the seal aggregate, and complete set up (ie completion emulsion break and adhesion) can take some time. Thus bitumen will come into contact with vehicle tyres and pick-up or skid resistance problems may occur.

For this reason the use of enrichments should normally be limited to low traffic flow situations where pick-up will be minimal and a temporary reduction in skid resistance will not create a significant hazard. When used in other circumstances more stringent precautions than normal will be required to avoid inconvenience and hazards to the public.

5.2 Design

Enrichment design is based on filling available seal voids to the extent that the added binder will successfully hold the aggregate against the forces imposed by traffic, and in satisfying constraints imposed by skid resistance and other requirements. The method presented is directed at achieving seal life extensions of at least four years.

5.2.1 Design Units

The first step in design is to select appropriate design units, that is sections of road for which the design inputs such as surface texture are similar. The sectioning of road into practical design units should be initially based on visual examination and modified as required following sand patch surface texture measurements. A minimum of 10 surface texture measurements per design unit or lot will normally be required.

A common difficulty with selection of design units will be dealing with the different surface textures of the wheel track and between wheel track sections of road. Separate surface texture measurements should be carried out for these two conditions and separate trial designs completed for both. In many circumstances a compromise design which satisfies both conditions will be possible. This compromise should not include making the wheel track position unsafe from the viewpoint of final surface texture.

Where suitable compromise cannot be achieved it may be possible to spray different application rates across the seal by judicious cutting off of spray nozzles. Alternatively another type of treatment such as resealing may be required.

5.2.2 Initial Residual Binder Application Rate

The initial residual binder application rate should be calculated by subtracting the desired final texture depth from the average existing texture depth of the design unit being considered. The difference in texture depth in mms can be equated directly to a rate in L/m^2 (ie 1 mm texture depth is the equivalent of 1 L/m^2). This design rate must then be checked against various constraints directed at ensuring maximum life and minimum problems.

5.2.3 Minimum Application Rate

There is a lower limit to enrichment application rates beyond which an economic seal life extension will not be achieved. This will depend on economic circumstances, however, in general experience indicates that residual rates of less than 0.4 L/m² are unlikely to be economically viable as seal life extensions of less than 4 years may result.

The initial design rate should be checked against this criteria and if it does not comply alternative treatments such as a reseal should be considered.

5.2.4 Maximum Application Rate

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The initial design rate should be checked against this criteria and if it does not comply alternative treatments such as a reseal should be considered.

5.2.5 Maximum Application Rate

Residual application rates of great than about 0.7 L/m² will involve prolonged setting times and an increased risk of pick-up by traffic. For this reason unless steps can be taken to avoid pick-up problems the initial design application rate should be checked against this criteria. Where the design rate exceeds this limit the design should be reduced to 0.7 L/m² or alternative treatments should be considered unless circumstances are such that pick-up is not likely to occur.

5.2.6 Maximum Life

Trials indicate that maximum enrichment life is achieved by limiting the final surface texture after over spraying to a maximum of 2.0 mm. Design application rates should be checked against this criteria as indicated in the design worksheet. Where a greater final texture depth is calculated alternative treatments such as a reseal or two-coat enrichment should be considered.

5.2.7 Conversion to Field Application Rate

The residual design application rate must be converted to a field application rate for dilute bitumen emulsion. Emulsion conforming to AS 1160 contains 60% bitumen. When diluted with water in the ratio of 4 emulsion to one of water the bitumen concentration is reduced to 48%. Conversion from a residual rate to a dilute field application rate may be obtained by multiplying the former by 2.08.

REFERENCES

SUBJECT	Bituminous Materials
CLASSIFICATION	Internal
KEY WORDS	Enrichment Design Seal Bitumen

APPENDIX A

ECONOMIC ANALYSIS

1. The following analysis considers alternative resurfacing strategies for a section of road which was assumed to have a total pavement life of 35 years. The initial surface treatment (eg prime and seal) was assumed to have a life of 13 years but the cost was ignored as it was common to all strategies. It was further assumed that current reseal costs were $1.75/m², enrichment costs were $0.70/m², and that a 10% discount rate was applicable. Strategies combining enrichments with lives varying from 3 to 5 years which reseals were considered in comparison to a strategy using only reseals to achieve the necessary total life extension of at least 22 years.

2. **Plan A – Reseals Only**

First retreatment	reseal 1	life 14 years
Second retreatment	reseal 2	life 8 years *

Present Worth (PW) Reseal 1	=	$1.75/m²
PW Reseal 2 = cost x Present Worth Factor (PWF) 14,10%	=	1.75 x 0.2633
	=	$0.460/m²
Total PW	=	$2.210/m²

Annualised Cost	=	Total PW x Capital Recovery Factor (CRF) 22,10%
	=	2.210 x 0.1140
	=	$0.252/m²

* Surfacing life limited by total pavement life of 35 years.

3. Plan B

First retreatment	Enrichment 1	life 3 years
Second retreatment	Reseal 1	life 14 years
Third retreatment	Enrichment 2	life 3 years
Fourth retreatment	Enrichment 3	life 2 years * (assumes sufficient texture depth available)

Present Worth Enrichment 1			=	$0.70/m²
PW Reseal	= cost x PWF 3, 10	= 1.75 x 0.7513	=	$1.315
PW Enrichment 2	= cost x PWF 17, 10	= 0.70 x 0.1978	=	$0.138
PW Enrichment 3	= cost x PWF 20, 10	= 0.70 x 0.1486	=	$0.104
		Total PW	=	$2.257

Annualised Cost = Total PW x CRF 22, 10%
= 2.257 x 0.1140
= $0.257/m²

* Surfacing life limited by total pavement life of 35 years.

4. Plan C

First retreatment	Enrichment 1	life 4 years
Second retreatment	Reseal 1	life 14 years
Third retreatment	Enrichment 2	life 4 years

Present Worth Enrichment 1			=	$0.70/m²
PW Reseal 1	= cost x PWF 4,10%	= 1.75 x 0.6830	=	$1.195
PW Enrichment 2	= cost x PWF 16,10%	= 0.70 x 0.2176	=	$0.152
		Total PW	=	$2.047

Annualised Cost = Total W x CRF 22, 10%
= 2.047 x 0.1140
= $0.233/m²

5. Plan D

First retreatment	Enrichment 1	life 5 years
Second retreatment	Reseal 1	life 14 years
Third retreatment	Enrichment 2	life 3 years *

Present Worth Enrichment 1			=	$0.70/m²
PW Reseal 1	= cost x PWF 5, 10%	= 1.75 x 0.6209	=	$1.087
PW Enrichment 2	= cost x PWF 19,10%	= 0.70 x 0.1635	=	$0.114
		Total PW	=	$1.901

Annualised Cost = Total W x CRF 22, 10%
= 1.901 x 0.1140
= $0.217/m²

* Surfacing life limited by total pavement life of 35 years.

6. The results of the analyses indicate that in comparison to the reseal only strategy, Case B (enrichment life 3 years) is about 2% dearer, Case C (enrichment life 4 years) is about 8% cheaper and Case D (enrichment life 5 years) is about 14% cheaper. That is provided an enrichment life of about 4 years is achieved the use of this technique in the circumstances examined is significantly cheaper than resealing.

APPENDIX B

ENRICHMENT DESIGN WORKSHEET

BINDER 4:1 CRS/50 BITUMEN EMULSION : WATER

1.	Division		Pilbara
2.	Road		North West Coastal Hwy
3.	Section		1200-1205 SLK
4.	Type of surface to be enriched		14mm Seal
5.	Existing surface texture for design unit	T_1	2.3 mm
6.	Final surface texture required for skid resistance (normally 1.0 mm)	T_2	1.0 mm

CALCULATIONS

1.	Initial residual binder application rate	$B_1 = T_1 - T_2$	1.3 L/m^2
2.	Binder Rate Checks:		
2.1	Adequate binder B1 < 0.4 L/m^2	Yes – proceed to step 2.2 No – enrichment life likely to be uneconomic, consider alternatives	
2.2	Maximum rate to avoid pick-up, run-off $B_1 < 0.7$ L/m^2	Yes – B_1 suitable proceed to step 3 No – make B1 – 0.7 L/m^2 proceed to step 2.3	
2.3	Maximum desirable remaining texture depth $T_2 - 0.7 < 2.0$ mm	Yes – $B_1 = 0.7$ L/m^2 proceed to step 3 No – enrichment life may be uneconomic, consider alternatives	
3.	Final dilute application rate BD	$BD = B_1 \times 2.08$	0.7 x 2.08 = 1.46 L/m^2

APPENDIX C

ENRICHMENT DESIGN WORKSHEET

BINDER 4:1 CRS/50 BITUMEN EMULSION : WATER

1.	Division		
2.	Road		
3.	Section		
4.	Type of surface to be enriched		
5.	Existing surface texture for design unit	T_1	
6.	Final surface texture required for skid resistance (normally 1.0 mm)	T_2	

CALCULATIONS

1.	Initial residual binder application rate	$B_1 = T_1 - T_2$	
2.	Binder Rate Checks:		
2.1	Adequate binder B1 > 0.4 L/m^2	Yes – proceed to step 2.2 No – enrichment life likely to be uneconomic, consider alternatives	
2.2	Maximum rate to avoid pick-up, run-off $B_1 < 0.7$ L/m^2	Yes – B_1 suitable proceed to step 3 No – make B1 = 0.7 L/m^2 proceed to step 2.3	
2.3	Maximum desirable remaining texture depth $T_2 - 0.7 < 2.0$ mm	Yes – $B_1 = 0.7$ L/m^2 proceed to step 3 No – enrichment life may be uneconomic, consider alternatives	
3.	Final dilute application rate BD	BD = B_1 x 2.08	