SEALING IN ADVERSE WEATHER

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Abstract
This paper entails a study which discusses the topic of sealing in adverse weather conditions. The study seeks to evaluate the weather patterns over the past 10 to 20 years on the N3 Toll Route, the effect thereof on sealing activities, and possible alternatives that can be considered in order to accommodate the changing weather patterns.

1. INTRODUCTION

National Route 3 is one of the most heavily trafficked routes in South Africa, carrying on average between 12,000 and 34,000 vehicles per day. In order to maintain the functional requirements of the route, it is necessary to provide surface treatments that consist of a wearing course on which vehicular traffic can travel as well as protecting the pavement structure. One such wearing course that has been extensively utilised on the N3 Toll Route is that of bituminous seals, in particular bitumen rubber seals.

A bituminous seal is a common surface used to provide durable, waterproof, skid-resistant, all weather dust free surfacing, while at the same time protecting the underlying structural pavement layers from the effects of the environment and traffic (Technical Recommendation's for Highways TRH3, 2007). The successful construction of a surfacing seal is dependent on many factors including pavement structure and condition, traffic volumes, road geometry, the type of seal, binder selection, aggregate properties, weather conditions, construction practices including application rates of binder and aggregate, initial rolling, brooming, and opening to traffic (Committee of Land Transport Officials, 1998). Of particular interest for this paper are the ambient weather conditions under which seals are constructed.

In the recent past it has been debated that weather patterns may be changing, and as a result may have had a significant impact on the suitable period within which seal work is able to be undertaken. It has become common for seal contracts to over-run their contractual dates as a result of the impact of higher than expected rainfall as well as seal embargos, which do not allow for sealing during the colder months. Seal embargoes typically run between the beginning of May and the beginning of October.

The requirement for any seal to retain aggregate is guided by whether there is enough binder, with a low enough viscosity, to accept the aggregate to ensure proper embedment into the binder during the early stages of construction. The rate at which the viscosity increases and the amount of binder relative to the size of the aggregate will determine whether the aggregate remains embedded when colder climatic conditions prevails. The seal design requirements as per Technical Recommendation's for Highways TRH3 (2007), and Committee of Land Transport Officials (1998) is well established for conventional binders, emulsions and modified binders.

The standard specifications (Committee of Land Transport Officials, 1998) require that bitumen rubber seals are constructed when surface temperatures are 25°C and rising. The specifications do not provide minimum overnight temperature requirements when no seal work can be undertaken. The Technical Guideline for use of Modified Bituminous Binders in Road Construction (Technical Guideline TG1, 2007) provides a guideline that bitumen rubber seal work should not be undertaken when overnight temperatures are lower than 10°C. This recommendation is made in order to ensure good adhesion between the binder and the aggregate occurs during the initial days following the construction of the seal when the risk of aggregate loss is the highest.

In order to evaluate weather patterns along the N3 route, weather data was sourced from the South African Weather Bureau for Mooi River, Van Reenen, Harrismith, Vrede and Springs. The locations of Vrede and Springs were selected, as these are the closest weather stations to Villiers and Heidelberg, for which the South African Weather Bureau has current weather data for. The data obtained included minimum and maximum daily temperatures as well as daily rainfall records.

2. BITUMEN RUBBER

Technical Recommendation's for Highways TRH3 (2007), Design and Construction of Surfacing Seals, recommends that bitumen rubber binders be used in situations where high performance is required as well as for problem areas. The reasons for this relate to the excellent properties of bitumen rubber which include;

- the ability to retard reflective cracking and accommodate high deflections through the resilience and elastic recovery of the binder;
- the ability to apply more binder to a surface because of the resistance to flow at high temperatures; and
- the ability to provide increased UV protection and extend the life of a seal.

Bitumen rubber consists of a mixture of penetration grade bitumen, rubber crumbs and extender oil, blended at high temperatures, under controlled conditions and in specific ratios. The grade of the binder used is typically 80 penetration grade binder. The ratio of natural and synthetic rubber is important to the performance and properties of the bitumen rubber binder. The natural rubber provides elasticity and adhesion to the aggregate, and a minimum of 25% of natural rubber is normally specified (Technical Guideline TG1, 2007).

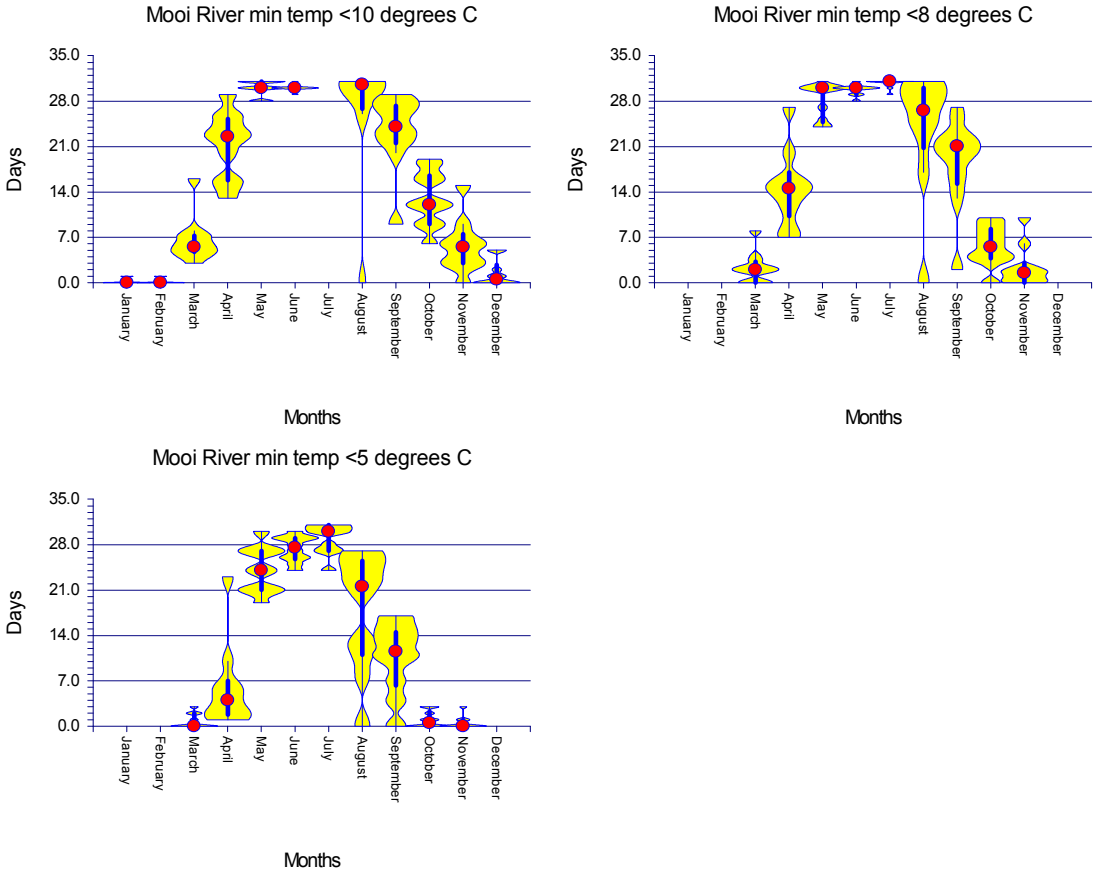
The extender oil used in the manufacture of bitumen rubber depends on the type of bitumen, the area to be sealed and the environmental conditions. The extender oil aids in the production of a flexible, elastic product with good adhesion properties while at the same time reducing temperature susceptibility. The minimum amount of extender oil is used so as to achieve the best possible performance properties (Judd, Jooste, Hattingh, Sadler, Muller., 2008). The percentage of rubber, by mass, used in the bitumen rubber blend is normally between 20% and 24% of the total mass of the blend. A number of performance requirements for the bitumen rubber blend are specified in COLTO (1998), as well as TG1 (2007), to ensure that the bitumen rubber performs as intended.

3. MINIMUM TEMPERATURE ANALYSIS

In the process of evaluating the data, violin plots were used to plot and assess the minimum temperature data. A violin plot is a combination of a box plot and two vertical density traces. The violin plot highlights the peaks and valleys of a variable distribution. The median (the mid-point in the frequency distribution) is indicated by a red circle. The upper quartile (75th percentile) and lower quartile (25th percentile) are indicated by the solid blue line. The density traces give the shape to the violin plot, the higher the density of data, the wider the trace.

3.1 Mooi River

Weather data for Mooi River is only available from 2000 to 2009 (10 years). The plots below indicate the distribution and median number of days of temperatures below 10ºC, 8ºC and 5ºC respectively.



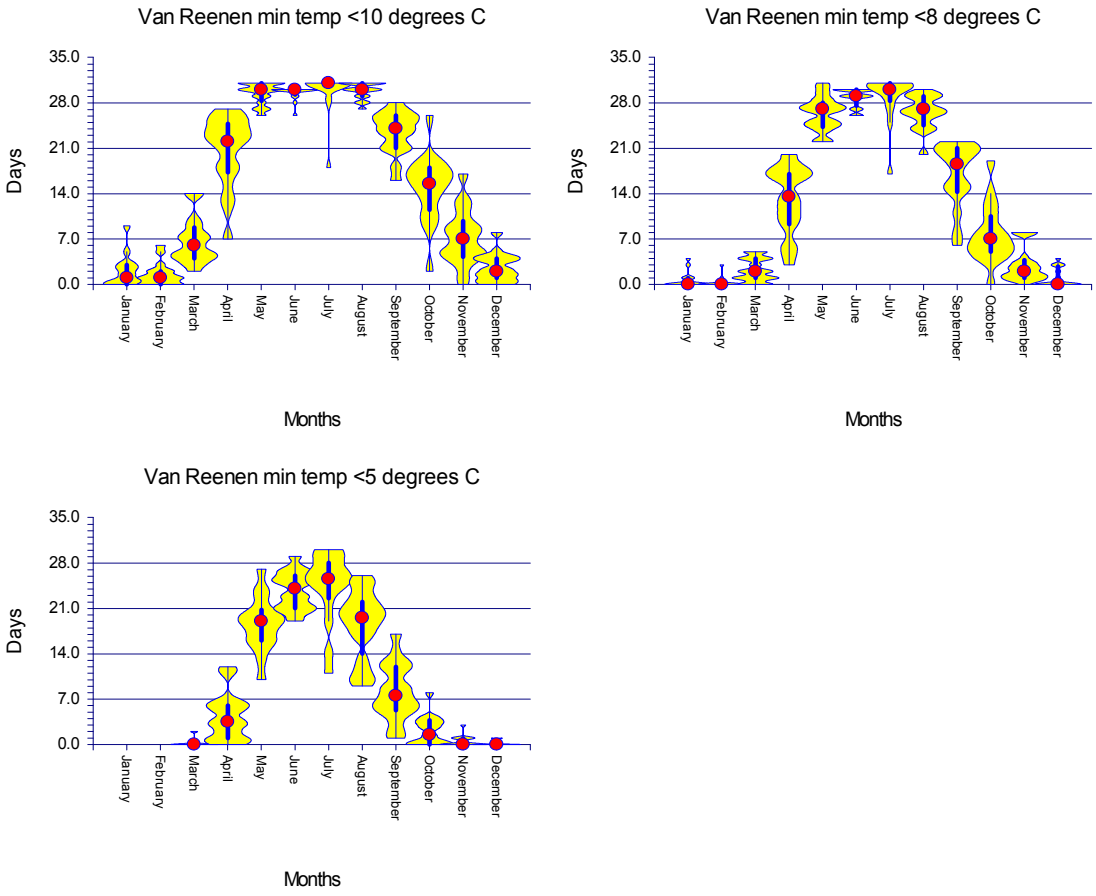
Currently the seal embargo applicable to all seal work on the N3 states that no sealing may be undertaken between the 1st of May and the 1st of October of any year (i.e. the colder months).

From the plots it is apparent that in the months of May, June, July, August and September, there are on average at least 23 days per month when minimum overnight temperatures are less than 10ºC. However, more interestingly, it is apparent that there are on average 22 days in April when the minimum overnight temperatures are less than 10ºC. This figure drops to 14 days and 4 days respectively when considering the number of days where overnight temperatures are less than 8ºC and 5ºC respectively.

Similarly in October, there are on average 12 days per month when the minimum overnight temperatures are less than 10ºC. This figure drops to 6 days and 1 day respectively when considering the number of days where overnight temperatures are less than 8ºC and 5ºC respectively.
If we were to use the current sealing best practice minimum overnight temperature guidelines, this would mean that virtually no sealing should be done during April, while only half of October is suitable for sealing.

3.2 Van Reenen

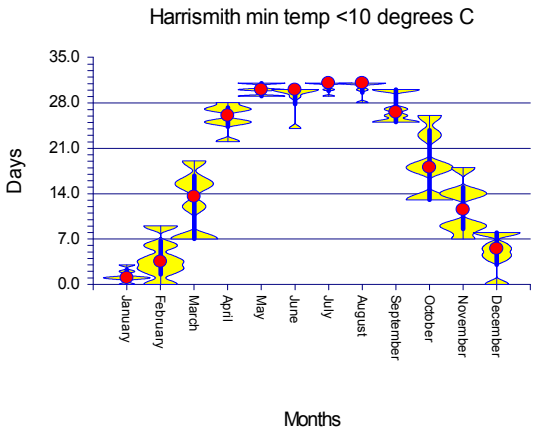
Weather data for Van Reenen is only available from 1993 to 2009 (17 years), as for Mooi River, the results indicate that virtually no sealing should be done during April, while only half of October is suitable for sealing, based on minimum overnight temperatures of 10ºC.

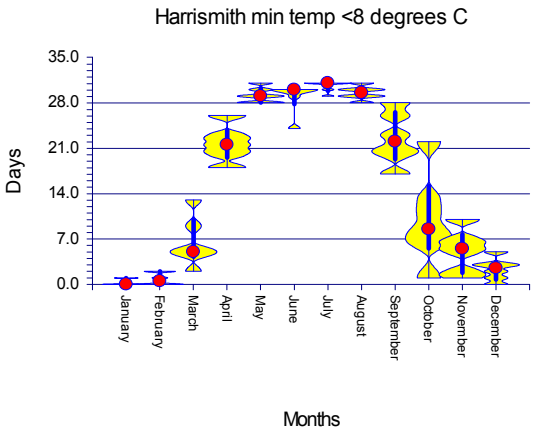


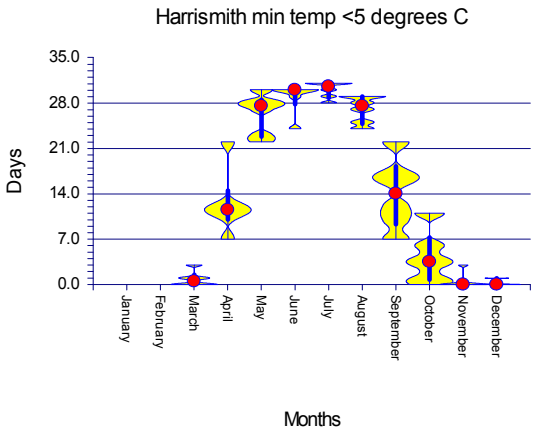
3.3 Harrismith

Weather data for Harrismith is only available from 1990 to 1999 (10 years). From the plots it is apparent that the overnight temperatures in Harrismith are more severe than Mooi River and Van Reenen (in fact than anywhere else on the route), there are on average 26 days in April when the minimum overnight temperatures are less than 10ºC. This figure drops to 22 days and 12 days respectively when considering the number of days where overnight temperatures are less than 8ºC and 5ºC respectively.

Similarly in October, there are on average 18 days per month when the minimum overnight temperatures are less than 10ºC. This figure drops to 9 days and 5 days respectively when considering the number of days where overnight temperatures are less than 8ºC and 5ºC respectively.
If we were to use the current sealing best practice minimum overnight temperature guidelines, this would mean that no sealing should be done during April, while more than half of October is not suitable for sealing.

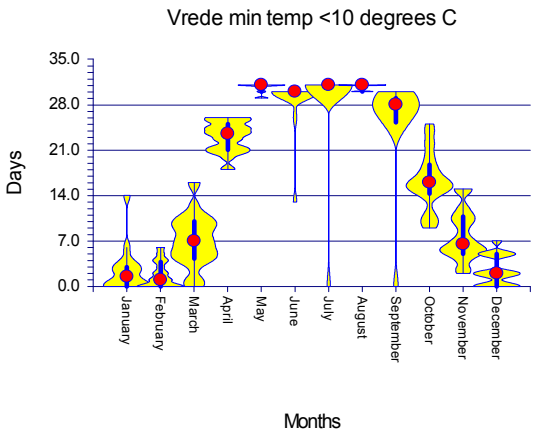


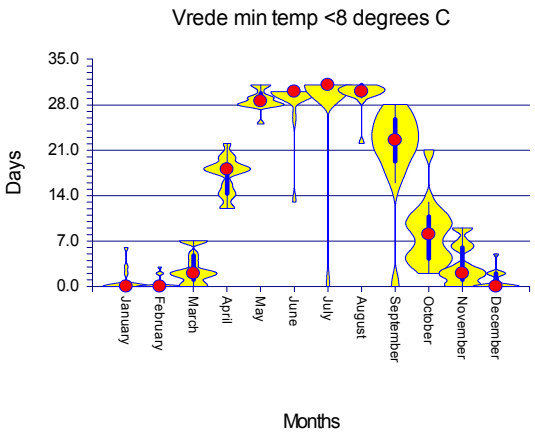


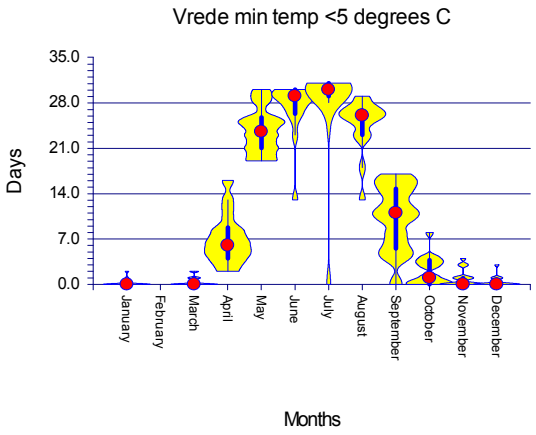


3.4 Vrede

Weather data for Vrede is only available from 1993 to 2009 (17 years). The weather pattern in Vrede is slightly different to Mooi River and Van Reenen with regards to minimum overnight temperatures. There would appear to be more variability in overnight temperatures in January and February, however the general trend of April and October not being suitable for sealing as a result of low overnight temperatures holds true. In April, there are 23 days per month where minimum overnight temperatures are less than 10ºC. In October there are 16 days where minimum overnight temperatures are less than 10ºC. The table below summarises the 10ºC, 8ºC, and 5ºC findings.

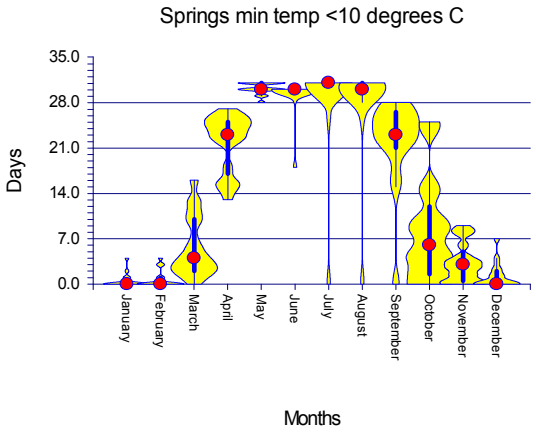


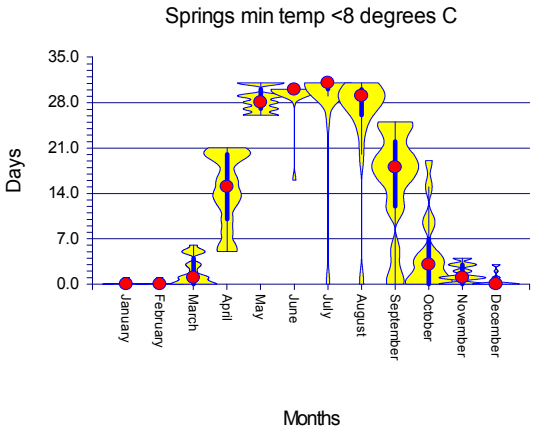


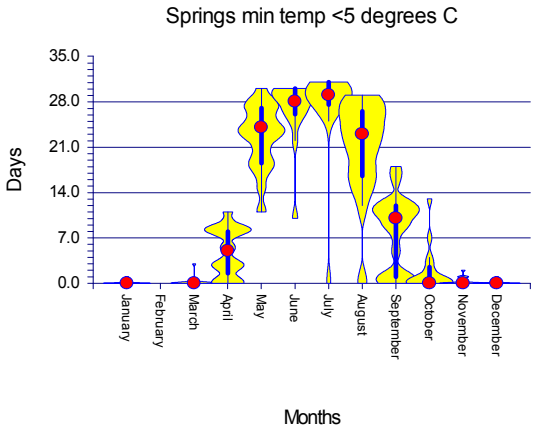


3.5 Springs

Weather data for Springs is only available from 1993 to 2009 (17 years). The weather pattern in Springs is similar to Vrede. The general trend of April and October not being suitable for sealing as a result of low overnight temperatures holds true. The table below summarizes the findings;







The table below summarizes the findings;

Table 1: Summary of temperature findings

LOCATION	MONTH	MEDIAN NO. DAYS <10ºC	MEDIAN NO. DAYS <8ºC	MEDIAN NO. DAYS <5ºC
Mooi River (2000-2009)	April	22	14	4
	October	12	6	1
Van Reenen (1993-2009)	April	22	13	4
	October	16	7	2
Harrismith (1990-1999)	April	26	22	12
	October	18	9	5
Vrede (1993-2009)	April	23	18	6
	October	16	8	1
Springs (1993-2009)	April	23	15	5
	October	6	3	0

As can be seen in Table 1, by adhering to the guidelines of restricting sealing activities when overnight temperatures fall below 10°C, the effective seal window in April is reduced by as much as 26 days, while for October the seal window is reduced by as much as 18 days.

4. RAINFALL ANALYSIS

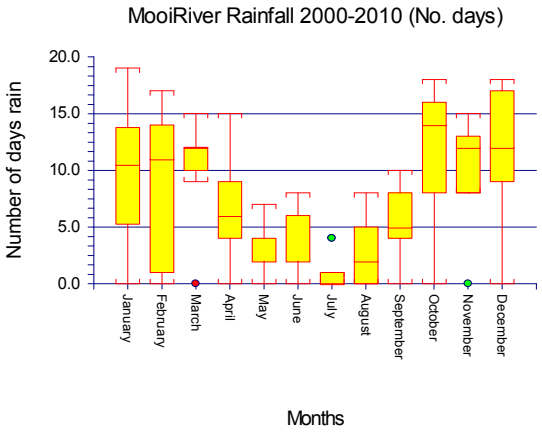
In the process of evaluating the rainfall data, box plots were used to plot and assess the data. A box plot is made up of a box (a rectangle) with various lines and points added to it. The top and bottom of the box are the 25th and 75th percentiles. The length of the box is thus the interquartile range (IQR). That is, the box represents the middle 50% of the data. The IQR is a popular measure of spread. A line is drawn through the middle of the box at the median (the 50th percentile). .

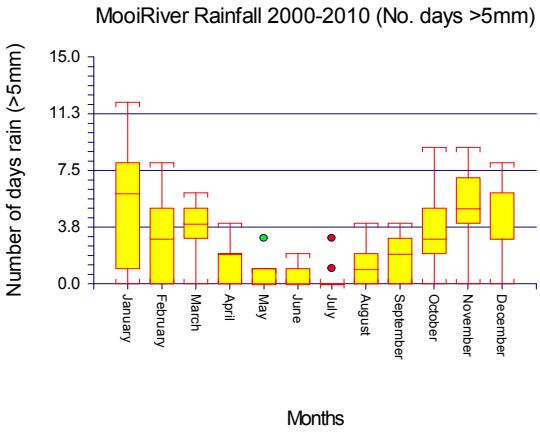
Values outside the upper and lower adjacent values are called outside values. Values that are under three IQRs from the 25th and 75th percentiles are called mild outliers. Those outside three IQRs are called severe outliers. Mild outliers are not unusual, but severe outliers are. Mild outliers are indicated by a green circle, while severe outliers are indicated by a red circle.

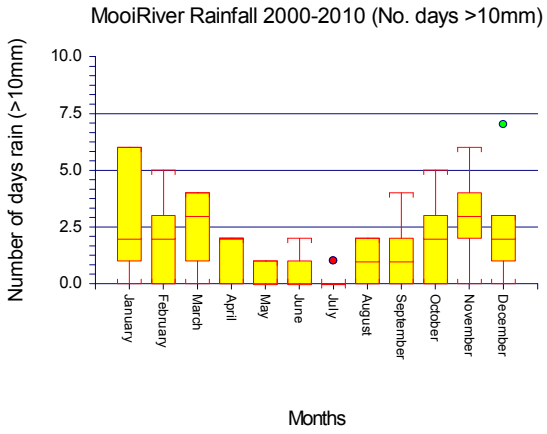
The box plots below illustrate the mean and spread of rainfall. The three plots represent;

- Number of days of recorded rainfall;
- Number of days of recorded rainfall in excess of 5mm; and
- Number of days of recorded rainfall in excess of 10mm.

4.1 Mooi River







The number of days of recorded rainfall in excess of 5mm and 10mm is of importance, as these are potentially days where work may be delayed as a result of rain. In particular this is important with regards to sealing activities as;

- Sealing cannot be undertaken in wet weather,
- Seals in their early life are generally sensitive to wet weather, and
- Sealing cannot be undertaken immediately after wet weather as the surface being sealed has to be allowed to dry adequately in order to avoid trapping moisture in the underlying layer.

From the rainfall in excess of 5mm box plot, and based on the inter-quartile range, it is evident that the highest average number of days of rainfall in excess of 5mm occurs during January and November respectively. It is also noted that there is the greatest spread and variability of rainfall in January and February. Rainfall tends to be fairly consistent during March, October, November, and December.

This information indicates that allowance should be made for between 3 days and 7 days of rain exceeding 5mm during March, October, November, and December (based on the inter-quartile range). The variability during January, and February, indicates that the number of days of rainfall in excess of 5mm may vary between 1 day and 8 days per month (based on the inter-quartile range).

4.2 Van Reenen

The highest average number of days of rainfall in excess of 5mm occurs during January, February and November respectively. It is also noted that there is the greatest spread and variability of rainfall in January, March and October. Rainfall tends to be fairly consistent during February, November, and December.

Allowance should be made for between 4 days and 9 days of rain exceeding 5mm during February, November and December (based on the inter-quartile range). The variability during January, March and October, indicates that the number of days of rainfall in excess of 5mm may vary between 2 days and 12 days per month (based on the inter-quartile range).

4.3 Harrismith

For Harrismith, the highest average number of days of rainfall in excess of 5mm occurs during January, February and November respectively. It is also noted that there is the greatest spread and variability of rainfall in January, March and October. Rainfall tends to be fairly consistent during February, November, and December.

Based on the historical information, allowance should be made for between 3 days and 8 days of rain exceeding 5mm during February, November and December (based on the inter-quartile range). The variability during January, March and October, indicates that the number of days of rainfall in excess of 5mm may vary between 1 day and 9 days per month (based on the inter-quartile range).

4.4 Vrede

The highest average number of days of rainfall in excess of 5mm occurs during January, November and December respectively. It is also noted that there is the greatest spread and variability of rainfall in February, November and December. Rainfall tends to be fairly consistent during January, March and October.

Allowance should be made of between 3 and 6 days of rain exceeding 5mm during January, March and October (based on the inter-quartile range). The variability during February, November and December, indicates that the number of days of rainfall in excess of 5mm may vary between 0 days and 7 days per month (based on the inter-quartile range).

4.5 Springs

For the Springs rainfall data, it is apparent that the highest average number of days of rainfall in excess of 5mm occurs during January, November and December respectively. It is also noted that there is the greatest spread and variability of rainfall in February, November and December. Rainfall tends to be fairly consistent during January, March and October.

Based on the data recorded, allowance should be made of between 3 and 6 days of rain exceeding 5mm during January and March (based on the inter-quartile range). The variability during February, October, November and December, indicates that the number of days of

rainfall in excess of 5mm may vary between 0 days and 7 days per month (based on the inter-quartile range).

5. ALTERNATIVES

In order to extend the seal window and ensure that construction of seals can continue during times of adverse weather where the ambient temperatures are starting to decrease to 10°C and below, and there is a possibility of rainfall on a fresh seal, alternatives can be considered;

- alternative product selection;
- alternative construction methods; and
- attention to detail during construction (actually runs together with the first two alternatives).

Further there are three alternatives related to product selection;

- the cutback approach (various levels and types of cutters depending on the product type);
- the wet pre-coating approach (controversial but this has been employed); and
- the emulsion and / or fog spray approach.

None of these options are considered to be perfect solutions, and therefore depending on the site conditions, experience of the site personnel and level of supervision, the level of success may vary. However, if managed responsibly, the extension of the seal window is achievable, and has been done so successfully in the past.

5.1 Alternative Construction Methods

Alternative construction methods that have been utilised in the past in order to reduce risk of aggregate loss include;

- tighter control in terms of the distance that the binder distributor is allowed to spray;
- higher level of attention during rolling activities, such as the number of passes, type of rolling;
- close monitoring of the effect of the traffic post construction of the seal;
- proper monitoring of changes in weather conditions; and
- road closures of affected areas.

Overall these are considered to be best practice guidelines to ensure successful construction of seals, but are recognised as being of significant importance during sealing activities when adverse weather may affect the seal performance.

Best practices related to the successful use of cutback or winter-grade alternatives has however not yet been captured formally in guidelines, and the experience in South Africa is very dependent on the relationships between suppliers, contractors, consultants and clients.

5.2 Alternative Product Selection

Product selection for sealing in adverse weather conditions follows a basic principle of moving to a softer binder grade to ensure that binder can accept the aggregate and hold it at low temperatures, or utilising the normally specified grades of binders but then to modify those binders by cutting back the binder.

Cutting back the normally specified binder results in;

- temporary reduction of the binder viscosity to be able to accept and hold the aggregate;
- adequate wetting of the aggregate to hold the aggregate;
- evaporation of volatile cutters over time; and
- residual binders revert back to their original seal grades.

5.3 Bitumen Rubber Cut Back

Bitumen rubber cut back binders were originally developed in South Africa in 1991, to alleviate the limitation that bitumen rubber could only be used during the warmer summer months.

The introduction of a cutter to the bitumen rubber blend reduces the viscosity of the binder at lower temperatures, thereby providing improved adhesion between the binder and aggregate for newly constructed seals. The amount of cutter added to the bitumen rubber binder depends on the ambient road and overnight temperatures that the newly constructed seal will be subjected to. The lower the temperatures the more cutter is required to be able to successfully undertaken the seal work.

There are two commonly referred to grades of bitumen rubber which contain different amounts of cutter, which are used under different conditions. The autumn grade typically contains between 2% and 4% of cutter and is suitable for overnight temperatures of down to 7°C, while the winter grade is suitable for overnight temperatures of down to 0°C. The amount of cutter used for the winter grade binder is in the order of 6% to 8%. The table below provides a comparison of the typical results that can be expected of the various bitumen rubber grades (Tosas, 2006).

Table 2: Comparison of the typical properties of various bitumen rubber grades

PROPERTY		UNIT	TEST METHOD	NATIONAL SPECIFICATION		TYPICAL RESULTS		
				SR-1 (SEAL)		ARM-R SHIELD GRADES		
				MIN	MAX	SUMMER	AUTUMN	WINTER
Compression	5 min	%	MB-11	70	-	91	89	82
recovery	1 hour	%		70	-	89	83	70
	4 days	%		25	45	44	42	28
Softening point	R&B	°C	MB-17	55	35	58	54	49
Resilience		%	MB-10	13	35	30	19	5
Flow		Mm	MB-12	15	70	31	55	80
Dynamic Flow		dPa.s	MB-13	20	40	28	28	25

There are however disadvantages to the use of cutters in bitumen rubber binders, as the cutter changes some of the properties of the binder. The use of a cutter may have a detrimental effect on the early life performance of the binder, where the resilience of the binder is greatly reduced. The effect thereof is a loss of the 'toughness' of the binder, especially where a seal may be subjected to high stress environments.

There may be a negative effect on freshly constructed asphalt below the seal, where the cutter in the bitumen rubber seal may cause the fresh asphalt layer to 'soften up' and may cause subsequent bleeding of the seal.

Further, if the bitumen rubber seal is being utilised as a Stress Absorbing Membrane Interlayer it is important to ensure that the seal is not overlaid too soon, as the volatiles from the cutter will cause the binder on the asphalt overlay to soften up and may result in the asphalt overlay failing. The volatiles from the seal need time to escape, to prevent the problem of softening up a fresh adjacent bituminous layer; which usually requires the action of traffic and / or hotter weather.

6. CONCLUSION AND RECOMMENDATION

Based on the study undertaken, it can be concluded that sealing during the month of April is very risky, as approximately 75% of the month of April experiences minimum overnight temperatures of less than 10 ºC. For the month of October, this figure is approximately 50% of the month, never mind the overnight temperatures of May and September. The consistency of the time period of the temperatures being less than 10ºC during the month of October, indicate that in general the temperatures are still low in the first two weeks of October. Further, depending on the location of the seal work being undertaken, allowance should be made in terms of programming for delays as a result of rainfall.

All in all this leaves a very limited window of opportunity to complete any seal work required. In order to ensure that as much seal work can be undertaken during the time available, it is necessary to consider the use of alternative methods. One such alternative is the use of a cut back bitumen rubber binder to ensure that sealing can be undertaken during the cooler months of April, May, September and October, as well as during periods where there is a possibility of rainfall on a fresh seal.

There are however considerations that need to be taken into account to ensure that the seal is successful. Experience has shown that cutters can effectively be used in circumstances where overnight temperatures are as low as 7°C which effectively increases the seal window by 14 days, which is considered to be significant.

7. REFERENCES

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