# DESIGNING A ONE-AND-A-THIRD SEAL USING MARGINAL AGGREGATE BY MEANS OF THE MODIFIED TRAY TEST

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## INTRODUCTION

During February 2000, heavy rains in the Limpopo Province of South Africa, resulted in major floods causing severe damage to the road infrastructure. Road P278/1, from Wyliespoort to Sibasa, had to be closed as a result of wash-aways, damage to fills as well as mudslides in the Thate Vondo Pass. Emergency repairs and opening of the pass by removing the mudslides further damaged the surfacing and the layers of the road. Limited funds were allocated for emergency road repairs, patching and base reconstruction. Owing to the wide-ranging repair works that had to be undertaken at the time, the Northern Province Roads Agency (NPRA) experienced shortages in material resources, such as crushed stone for chip sealing. Special measures had to be taken to ensure that the quality of work was maintained despite the shortages. Hence, the NPRA requested consultants and CSIR-Transportek to investigate alternative designs for chip seals for, for instance, the reconstructed portions of P278/1.

## BACKGROUND

In order to ensure optimal retention of particularly the 6.7 mm chips during sealing and to limit excessive early loss of these chips, CSIR-Transportek formalized an optimal chip sealing procedure, referred to as a “one-and-a-third seal”, using a slightly more open spread of the 13.2 mm chippings, followed by the application of 6.7 mm chippings to effectively fill the created voids, ensuring very little loss/whip-off of the 6.7 mm chips. This procedure has now been successfully applied on a number of other NPRA projects.

When designing seals with more than one layer of stone, it is usually assumed that the stone of both the first and second layer are fairly cubical in shape. In such a case, it is fairly easy to design a normal double seal. However, in certain areas of South Africa and the African continent, well-shaped aggregates are not always locally available and have to be imported at an excessive cost. Alternatively, one has to adjust the design in order to use locally available aggregate sources to the best of one’s ability.

In the latter case, one cannot use published design tables as they assume a certain relationship between the Average Least Dimension (ALD)(mm) of the stone and the voids in the layer. Use has therefore to be made of the modified tray test, which measures both the Effective Layer Thickness (ELT)(mm) and the true voids (%) in the layer. This method can be used for the design of both single and double seals. In the paper, the actual design of a double seal for the Northern Province is used as an example.

21st Annual South African Transport Conference
*‘Towards Building Capacity and Accelerating Delivery’*
ISBN: 0-620-28855-8

South Africa, 15 - 19 July 2002
Conference organised by: Conference Planners
CD-ROM produced by: Document Transformation Technologies

## DESIGN AND CONSTRUCTION OF THE ADJUSTED "DOUBLE" SEAL

### Practical design approach

The selected void and layer thickness from the modified tray curves are used in the CSIR design method as given in TRH 3 (1985). The new version of TRH 3 is also based on this method. An additional parameter is added to the old CSIR method to make provision for the upward displacement of binder from the existing surfacing.

From the curves in Figures 1 and 2 the first stone application (i.e. bottom layer) was selected and the second layer (i.e. top layer) was applied on top of the first layer to optimize the second layer of stone (see Figures 3 and 4). The stone applications give the true (accurate) void content and effective layer thickness of the combined seal that can be easily read of the developed curves (the so called finger print of the stone that is used for the design).

### Selection method used for the stone application rates

The bottom layer of stone is firstly placed in the tray in a nearly shoulder-to-shoulder packing, making certain that the stone does not lie in a double layer. The second layer of stone is then applied in steps of, say, 50 g. With each stone application rate, both the ELT and voids content in the layer are determined (see Figures 3 and 4). This process is continued until the second layer of stone completely covers the whole base area of the tray in such a manner that it interlocks effectively with the bottom layer of stone. Both the ELT and the voids content are plotted against the stone application rate in order to visually determine the stone application rate at which the ELT is fairly constant and the voids content increases slightly for small changes in stone application rate. This latter precaution will ensure that the seal does not fat-up. The stone application rate of the bottom layer was fixed at 620g (i.e. 12.4 kg/$m^3$ or 115.6 $m^2/m^3$). The second layer was applied on top. As for any seal, the embedment and wear of the aggregate have to be predicted from the corrected ball-penetration values, the hardness of the stone, as expressed by the 10%FACT value, and the design traffic on the road.

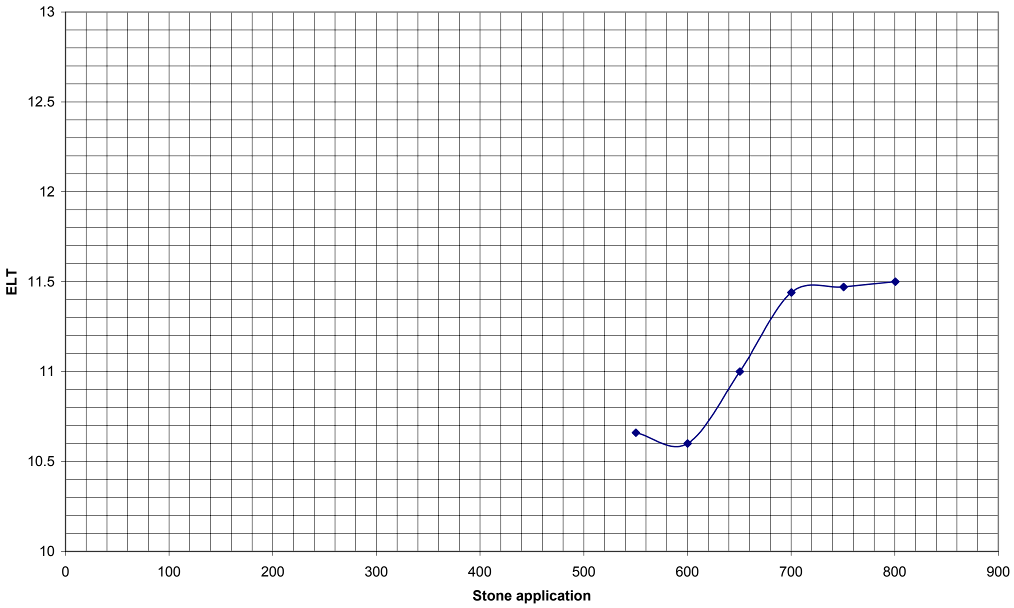


**Figure 1: Effective layer thickness (ELT) of bottom layer against stone application rate of bottom layer in modified tray test**

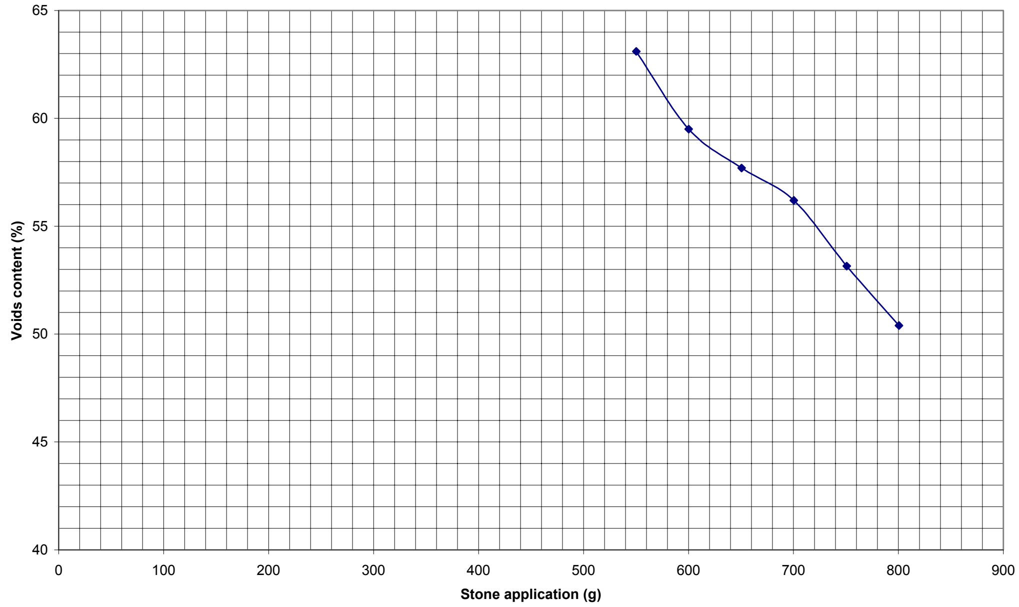


**Figure 2: Voids content of bottom stone layer against stone application rate in modified tray test**

In this case, the choice fell on the point where the mass of the second layer in the tray amounted to 250g. This produced a combined ELT of 12.2 mm and a void content of 48.9 per cent. The stone of both the first and second layers should also be evaluated in a shoulder-to-shoulder configuration to determine the ELTs and voids contents of the single layers. These values are required, together with the bulk voids of the stone, to determine the spread rate as well as the percentage of the spread rate of the second layer that should be applied to construct the required seal. In this case, 250g amounted to an application rate of 84 per cent.

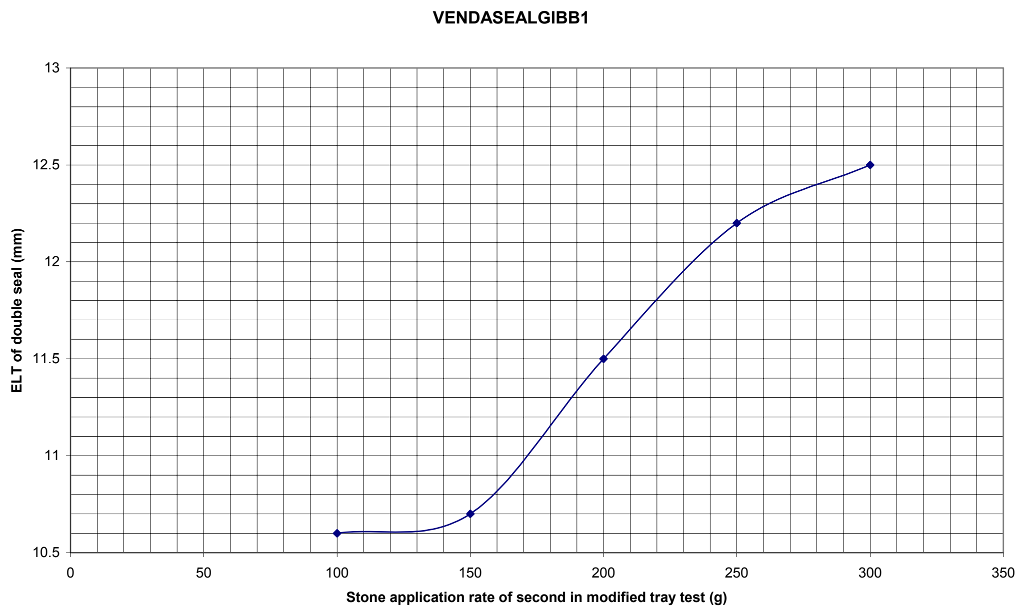


**Figure 3: ELT of double seal against stone application rate of second layer on top of first layer in modified tray test**

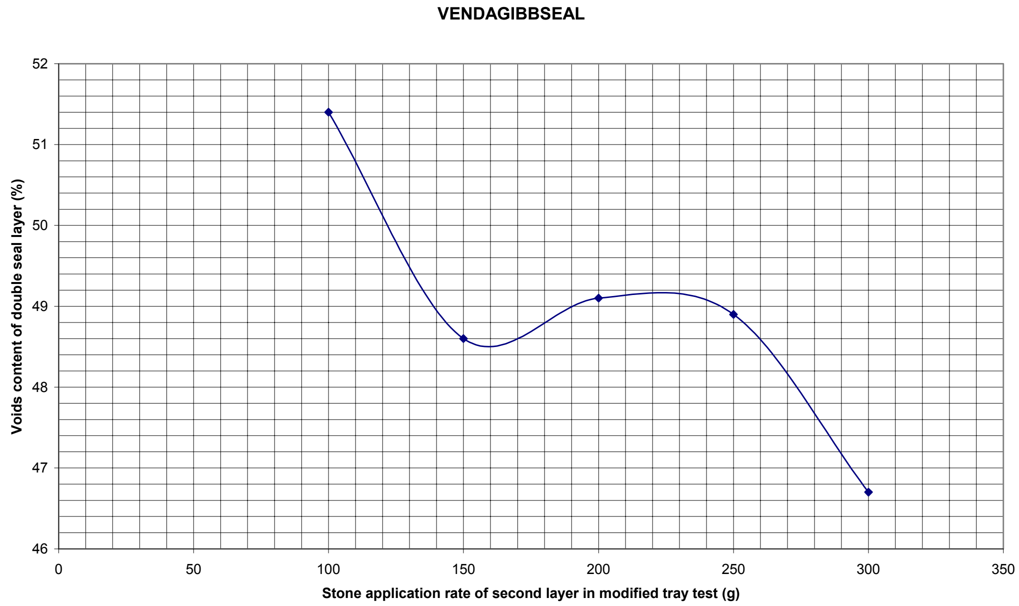


**Figure 4: Voids content of double seal against application rate of second layer on top of first layer in modified tray test**

**Two possible solutions derived from the curves**

**Figure 5: Stone application of small stone on top of large stone 3kg/m$^3$ (i.e. 432 m$^2$/m$^3$). Example of a single layer choke seal.**

**Figure 6: Stone application rate of small stone on top of large stone was 5 kg/m$^3$ (i.e. 259 m$^2$/m$^3$). Example of a "one-and-a-third seal".**

**Summary of stone application rates used in construction of the seal**

First application 13,2mm road stone=12,4 kg per m$^2$ = 115,6 m$^2$ / m$^3$

Second application 6,7mm road stone= 5 kg per m$^2$ = 259,4 m$^2$ / m$^3$

**Binder application**

The equivalent light vehicles (i.e. x 40 for each heavy vehicle)(elv) was used to check the sensitivity of the binder requirement to construct thus type of seal

Vehicles (elv) = 15000

Ball Penetration = 3 mm

**Table 1: Summary of the design calculations given in the appendix**

| Traffic (elv) | Ball Pen (mm) | Cold binder l / $m^2$ (displaced binder) | Cold binder l / $m^2$ (no displacement) |
|---|---|---|---|
| 10000 | 5 | 1,64 | 1,84 |
| 10000 | 4 | 1,76 | 1,93 |
| 10000 | 3 | 1,91 | 2,06 |
| 15000 | 5 | 1,48 | 1,70 |
| 15000 | 4 | 1,59 | 1,80 |
| 15000 | 3 | 1,75 | 1,93 |
| 15000 | 2 | 1,98 | 2,12 |
| 15000 | 1 | 2,42 | 2,50 |
| 20000 | 5 | 1,36 | 1,61 |
| 20000 | 4 | 1,48 | 1,71 |
| 20000 | 3 | 1,64 | 1,84 |

These analyses were done to assist the site staff to select the correct binder application if the site conditions varied from the given parameters.

**Other design methods used to check the design**

In practice the design is normally verified with other acceptable design methods; in this case a modified CPA 1985 was used.

CPA= ALD 13,2 mm + ALD 6,7 mm = 7,93 mm + 4,68 mm – 2 mm
(i.e. 2 mm punching)

=10,61 x 0,15
=1,59 l / $m^2$ cold binder

CPA= No-punching =12,61 x 0,15
=1,89 l / $m^2$ cold binder

**For general use the following design was used**

CSIR 1985= =1,75 l / $m^2$ cold binder was used

Deduction for fog-spray =1,75 – 0,15 l / $m^2$ (50% of fog-spray left on the stone)

=1,60 l / $m^2$ cold binder

=1,60 x 1,57 anionic emulsion (hot)

=2,512 l / $m^2$ anionic emulsion (hot)

**Summary of hot binder application rates used for construction of the seal (65 % anionic emulsion)**

First spray, tack coat =1,20 l / $m^2$ (hot)

Second spray, penetration =1,31 l / $m^2$ (hot)

Fog-spray (50% diluted) =1,00 l / $m^2$ (hot)

**Field construction process**

The following procedure was used to construct the seal:

- The first spray (or tack coat) was sprayed at 1,2 l /$m^2$.
- Followed by the 13,2 mm stone (un-coated) at 115,5 $m^2$ / $m^3$.
- The 13,2 mm stone layer was lightly rolled with a 5 to 7 tonne steel-wheel roller followed by a 16 to18 ton pneumatic-tyred roller (PTR)(See Figure 8 for the look of the completed bottom layer of stone).
- The second spray (penetration) was sprayed at 1,30 l /$m^2$.
- Followed by the second 6,7 mm stone (un-coated) at 260 $m^2$ / $m^3$.
- The 6,7 mm stone layer was then rolled with a 5 to 7 tonne steel-wheel roller followed by a 16 to 18 ton pneumatic-tyred roller (PTR). The layer was broomed to broom off the excess stone and then re-rolled with the PTR (see Figure 9: for the look of the completed second layer of stone).
- The fog-spray of 1,0% (50% diluted) was then sprayed two days later (see Figure 10 for the look of completed seal after the fog-spray).

**FIGURE 8: Close up view of stone application on bottom layer**

**Figure 9: Close-up view of the second layer on top of the first layer before application of the fog-spray**

**Figure 10: Close up view of the seal after one year**

This seal technique because of the lower stone requirements led to the following saving in the stone application:

- 10 % saving in the stone application of 13,2 mm stone.
- No brooming of the 13,2 mm stone layer necessary with less back chipping.
- 35% saving in the application of the 6,7mm stone.

Note:

- The final seal only had a limited amount of surplus 6,7 mm stone available, so this seal technique is also more traffic friendly over and above the saving in stone. The 6,7 mm stone can also be broomed off more easily and there is almost no surplus stone on the shoulder that has to be removed up afterwards.

- This seal structure is quite common in the field and lots of “double” seals end up like this type of seal because of the shape of the stone on site and the choice of binder specified. The first basic principle if heavy stone loss of the top layer occurs during seal construction is to open up the bottom layer of stone until the stone loss of the top layer subsides. The final seal then normally ends up somewhere between the two options available and then also with too much binder (because the binder is also increased to stop the stone loss). It is therefore more advantages to design this type of seal than to end up with this type of seal in a uncontrolled manner.

- The Resident Engineer on site, Mr. D Mans, found that the 6,7 mm stone when it was less flaky tend to crushed less and meshed more readily with the 13,2 mm stone as when it was more flaky.

## CONCLUSIONS

If the design application procedure of this paper is followed, chip loss/whip-off can be reduced and controlled. Marginal quality chips can be better utilized by embedding effectively and forming a tight matrix. The same approach has since successfully be followed in designing a number of other seals in the Limpopo Province.

## ACKNOWLEDGEMENTS

The authors appreciate the approval of the Northern Province Road Agency, Polokwane, the Director of Transportek, the project managers, Messrs SNA Consulting Engineers, and the contractor, Messrs Ekagen Construction to present this information at this conference.

## APPENDIX

SEALDOUBLE(ELT,V)

| | | | | | |
|---|---|---|---|---|---|
| ELT1(mm)= | 10.6 | VOIDS(%)= | 57.5 | BULK VOIDS(%)= | 48.2 |
| STONE (nominal spread rate)= | 8.70 l/m^2 | | 114.98 m^2/m^3 | Appl (%) | 100 |
| ELT2(mm)= | 4.47 | VOIDS(%)= | 52.5 | BULK VOIDS(%)= | 53.63 |
| STONE (nominal spread rate)= | 3.85 l/m^2 | | 259.99 m^2/m^3 | Appl (%) | 84 |
| ELTdouble (mm)= | 12.2 | VOIDSdouble(%)= | 48.9 | | |

| | | |
|---|---|---|
| TRAFFIC (elv) = | 10000 | |
| Corrected Ball Penetration = | 5 | |
| Hardness of stone (10%FACT)= | 260 | |
| Embedment due to traffic (mm) = | 2.270 | |
| Layer thickness loss (dry roll)(mm) = | 1.1 | |
| Fractional binder displacement due to stone embedment (dry roll) = | 0.385771 | |
| Maximum allowable voids filled with binder (42% single, 55% double) = | 55 | |
| Wear due to traffic (mm) = | 0.835 | |
| Required texture depth (skid resistance)(mm) = | 0.7 | |
| Available void fraction = | 0.271 | |
| Minimum Void fraction = | 0.276 | |
| Maximum nominal quantity cold binder (normal life)(l/m^2) = | 1.62 | 2.065321 |
| Minimum nominal quantity cold binder (normal life)(l/m^2) = | 1.64 | 1.838675 |
| Texture depth of existing surface (mm) = | 1.55 | |
| Texture depth binder requirement (l/m2) = | PRETREAT | |
| Life expectancy (minimum application rate)(years) = | 9.86 | 11.28925 |

SEALDOUBLE(ELT,V)

| | | | | | |
|---|---|---|---|---|---|
| ELT1(mm)= | 10.6 | VOIDS(%)= | 57.5 | BULK VOIDS(%)= | 48.2 |
| STONE (nominal spread rate )= | 8.70 l/m^2 | | 114.98 m^2/m^3 | Appl (%) | 100 |
| ELT2(mm)= | 4.47 | VOIDS(%)= | 52.5 | BULK VOIDS(%)= | 53.63 |
| STONE (nominal spread rate )= | 3.85 l/m^2 | | 259.99 m^2/m^3 | Appl (%) | 84 |
| ELTdouble (mm)= | 12.2 | VOIDSdouble(%)= | 48.9 | | |

| | | |
|---|---|---|
| TRAFFIC (elv) = | 10000 | |
| Corrected Ball Penetration = | 4 | |
| Hardness of stone (10%FACT)= | 260 | |
| Embedment due to traffic (mm) = | 2.084 | |
| Layer thickness loss (dry roll)(mm) = | 1.1 | |
| Fractional binder displacement due to stone embedment (dry roll) = | 0.385771 | |
| Maximum allowable voids filled with binder (42% single, 55% double) = | 55 | |
| Wear due to traffic (mm) = | 0.835 | |
| Required texture depth (skid resistance)(mm) = | 0.7 | |
| Available void fraction = | 0.296 | |
| Minimum Void fraction = | 0.295 | |
| Maximum nominal quantity cold binder (normal life)(l/m^2) = | 1.77 | 2.171656 |
| Minimum nominal quantity cold binder (normal life)(l/m^2) = | 1.76 | 1.932234 |
| Texture depth of existing surface (mm) = | 1.55 | |
| Texture depth binder requirement (l/m2) = | PRETREAT | |
| Life expectancy (minimum application rate)(years) = | 10.05 | 11.37189 |

SEALDOUBLE(ELT,V)

| | | | | | |
|---|---|---|---|---|---|
| ELT1(mm)= | 10.6 | VOIDS(%)= | 57.5 | BULK VOIDS(%)= | 48.2 |
| STONE (nominal spread rate )= | 8.70 l/m^2 | | 114.98 m^2/m^3 | Appl (%) | 100 |
| ELT2(mm)= | 4.47 | VOIDS(%)= | 52.5 | BULK VOIDS(%)= | 53.63 |
| STONE (nominal spread rate )= | 3.85 l/m^2 | | 259.99 m^2/m^3 | Appl (%) | 84 |
| ELTdouble (mm)= | 12.2 | VOIDSdouble(%)= | 48.9 | | |
| TRAFFIC (elv) = | 10000 | | | | |
| Corrected Ball Penetration = | 3 | | | | |
| Hardness of stone (10%FACT)= | 260 | | | | |
| Embedment due to traffic (mm) = | 1.843 | | | | |
| Layer thickness loss (dry roll)(mm) = | 1.1 | | | | |
| Fractional binder displacement due to stone embedment (dry roll) = | 0.385771 | | | | |
| Maximum allowable voids filled with binder (42% single, 55% double) = | 55 | | | | |
| Wear due to traffic (mm) = | 0.835 | | | | |
| Required texture depth (skid resistance)(mm) = | 0.7 | | | | |
| Available void fraction = | 0.331 | | | | |
| Minimum Void fraction = | 0.320 | | | | |
| Maximum nominal quantity cold binder (normal life)(l/m^2) = | 1.98 | | 2.326342 | | |
| Minimum nominal quantity cold binder (normal life)(l/m^2) = | 1.91 | | 2.058946 | | |
| Texture depth of existing surface (mm) = | 1.55 | | | | |
| Texture depth binder requirement (l/m2) = | PRETREAT | | | | |
| Life expectancy (minimum application rate)(years) = | 10.36 | | 11.55715 | | |

SEALDOUBLE(ELT,V)

| | | | | | |
|---|---|---|---|---|---|
| ELT1(mm)= | 10.6 | VOIDS(%)= | 57.5 | BULK VOIDS(%)= | 48.2 |
| STONE (nominal spread rate )= | 8.70 l/m^2 | | 114.98 m^2/m^3 | Appl (%) | 100 |
| ELT2(mm)= | 4.47 | VOIDS(%)= | 52.5 | BULK VOIDS(%)= | 53.63 |
| STONE (nominal spread rate )= | 3.85 l/m^2 | | 259.99 m^2/m^3 | Appl (%) | 84 |
| ELTdouble (mm)= | 12.2 | VOIDSdouble(%)= | 48.9 | | |
| TRAFFIC (elv) = | 15000 | | | | |
| Corrected Ball Penetration = | 5 | | | | |
| Hardness of stone (10%FACT)= | 260 | | | | |
| Embedment due to traffic (mm) = | 2.558 | | | | |
| Layer thickness loss (dry roll)(mm) = | 1.1 | | | | |
| Fractional binder displacement due to stone embedment (dry roll) = | 0.385771 | | | | |
| Maximum allowable voids filled with binder (42% single, 55% double) = | 55 | | | | |
| Wear due to traffic (mm) = | 0.835 | | | | |
| Required texture depth (skid resistance)(mm) = | 0.7 | | | | |
| Available void fraction = | 0.236 | | | | |
| Minimum Void fraction = | 0.248 | | | | |
| Maximum nominal quantity cold binder (normal life)(l/m^2) = | 1.41 | | 1.922447 | | |
| Minimum nominal quantity cold binder (normal life)(l/m^2) = | 1.48 | | 1.702032 | | |
| Texture depth of existing surface (mm) = | 1.55 | | | | |
| Texture depth binder requirement (l/m2) = | PRETREAT | | | | |
| Life expectancy (minimum application rate)(years) = | 9.66 | | 11.24938 | | |

SEALDOUBLE(ELT,V)

| | | | | | |
|---|---|---|---|---|---|
| ELT1(mm)= | 10.6 | VOIDS(%)= | 57.5 | BULK VOIDS(%)= | 48.2 |
| STONE (nominal spread rate )= | 8.70 | l/m^2 | 114.98 | m^2/m^3 Appl (%) | 100 |
| ELT2(mm)= | 4.47 | VOIDS(%)= | 52.5 | BULK VOIDS(%)= | 53.63 |
| STONE (nominal spread rate )= | 3.85 | l/m^2 | 259.99 | m^2/m^3 Appl (%) | 84 |
| ELTdouble (mm)= | 12.2 | VOIDSdouble(%)= | 48.9 | | |
| TRAFFIC (elv) = | 15000 | | | | |
| Corrected Ball Penetration = | 4 | | | | |
| Hardness of stone (10%FACT)= | 260 | | | | |
| Embedment due to traffic (mm) = | 2.355 | | | | |
| Layer thickness loss (dry roll)(mm) = | 1.1 | | | | |
| Fractional binder displacement due to stone embedment (dry roll) = | | | | 0.385771 | |
| Maximum allowable voids filled with binder (42% single, 55% double) = | | | | 55 | |
| Wear due to traffic (mm) = | 0.835 | | | | |
| Required texture depth (skid resistance)(mm) = | | | 0.7 | | |
| Available void fraction = | 0.260 | | | | |
| Minimum Void fraction = | 0.267 | | | | |
| Maximum nominal quantity cold binder (normal life)(l/m^2) = | | | 1.55 | | 2.02051 |
| Minimum nominal quantity cold binder (normal life)(l/m^2) = | | | 1.59 | | 1.797323 |
| Texture depth of existing surface (mm) = | 1.55 | | | | |
| Texture depth binder requirement (l/m2) = | PRETREAT | | | | |
| Life expectancy (minimum application rate)(years) = | | | 9.79 | 11.26708 | |

SEALDOUBLE(ELT,V)

| | | | | | |
|---|---|---|---|---|---|
| ELT1(mm)= | 10.6 | VOIDS(%)= | 57.5 | BULK VOIDS(%)= | 48.2 |
| STONE (nominal spread rate )= | 8.70 | l/m^2 | 114.98 | m^2/m^3 Appl (%) | 100 |
| ELT2(mm)= | 4.47 | VOIDS(%)= | 52.5 | BULK VOIDS(%)= | 53.63 |
| STONE (nominal spread rate )= | 3.85 | l/m^2 | 259.99 | m^2/m^3 Appl (%) | 84 |
| ELTdouble (mm)= | 12.2 | VOIDSdouble(%)= | 48.9 | | |
| TRAFFIC (elv) = | 15000 | | | | |
| Corrected Ball Penetration = | 3 | | | | |
| Hardness of stone (10%FACT)= | 260 | | | | |
| Embedment due to traffic (mm) = | 2.094 | | | | |
| Layer thickness loss (dry roll)(mm) = | 1.1 | | | | |
| Fractional binder displacement due to stone embedment (dry roll) = | | | | 0.385771 | |
| Maximum allowable voids filled with binder (42% single, 55% double) = | | | | 55 | |
| Wear due to traffic (mm) = | 0.835 | | | | |
| Required texture depth (skid resistance)(mm) = | | | 0.7 | | |
| Available void fraction = | 0.295 | | | | |
| Minimum Void fraction = | 0.294 | | | | |
| Maximum nominal quantity cold binder (normal life)(l/m^2) = | | | 1.76 | | 2.165673 |
| Minimum nominal quantity cold binder (normal life)(l/m^2) = | | | 1.75 | | 1.927124 |
| Texture depth of existing surface (mm) = | 1.55 | | | | |
| Texture depth binder requirement (l/m2) = | PRETREAT | | | | |
| Life expectancy (minimum application rate)(years) = | | | 10.04 | 11.36621 | |

SEALDOUBLE(ELT,V)

ELT1(mm)= 10.6 VOIDS(%)= 57.5 BULK VOIDS(%)= 48.2
STONE (nominal spread rate )= 8.70 l/m^2 114.98 m^2/m^3 Appl (%) 100
ELT2(mm)= 4.47 VOIDS(%)= 52.5 BULK VOIDS(%)= 53.63
STONE (nominal spread rate )= 3.85 l/m^2 259.99 m^2/m^3 Appl (%) 84
ELTdouble (mm)= 12.2 VOIDSdouble(%)= 48.9
TRAFFIC (elv) = 15000
Corrected Ball Penetration = 2
Hardness of stone (10%FACT)= 260
Embedment due to traffic (mm) = 1.725
Layer thickness loss (dry roll)(mm) = 1.1
Fractional binder displacement due to stone embedment (dry roll) = 0.385771
Maximum allowable voids filled with binder (42% single, 55% double) = 55
Wear due to traffic (mm) = 0.835
Required texture depth (skid resistance)(mm) = 0.7
Available void fraction = 0.350
Minimum Void fraction = 0.333
Maximum nominal quantity cold binder (normal life)(l/m^2) = 2.09 2.410227
Minimum nominal quantity cold binder (normal life)(l/m^2) = 1.98 2.123878
Texture depth of existing surface (mm) = 1.55
Texture depth binder requirement (l/m2) = PRETREAT
Life expectancy (minimum application rate)(years) = 10.55 11.68613

SEALDOUBLE(ELT,V)

ELT1(mm)= 10.6 VOIDS(%)= 57.5 BULK VOIDS(%)= 48.2
STONE (nominal spread rate )= 8.70 l/m^2 114.98 m^2/m^3 Appl (%) 100
ELT2(mm)= 4.47 VOIDS(%)= 52.5 BULK VOIDS(%)= 53.63
STONE (nominal spread rate )= 3.85 l/m^2 259.99 m^2/m^3 Appl (%) 84
ELTdouble (mm)= 12.2 VOIDSdouble(%)= 48.9
TRAFFIC (elv) = 15000
Corrected Ball Penetration = 1
Hardness of stone (10%FACT)= 260
Embedment due to traffic (mm) = 1.094
Layer thickness loss (dry roll)(mm) = 1.1
Fractional binder displacement due to stone embedment (dry roll) = 0.385771
Maximum allowable voids filled with binder (42% single, 55% double) = 55
Wear due to traffic (mm) = 0.835
Required texture depth (skid resistance)(mm) = 0.7
Available void fraction = 0.464
Minimum Void fraction = 0.405
Maximum nominal quantity cold binder (normal life)(l/m^2) = 2.77 2.953471
Minimum nominal quantity cold binder (normal life)(l/m^2) = 2.42 2.499757
Texture depth of existing surface (mm) = 1.55
Texture depth binder requirement (l/m2) = PRETREAT
Life expectancy (minimum application rate)(years) = 12.14 12.96371

SEALDOUBLE(ELT,V)

| | | | | |
|---|---|---|---|---|
| ELT1(mm)= | 10.6 VOIDS(%)= | 57.5 BULK VOIDS(%)= | | 48.2 |
| STONE (nominal spread rate )= | 8.70 l/m^2 | 114.98 m^2/m^3 Appl (%) | | 100 |
| ELT2(mm)= | 4.47 VOIDS(%)= | 52.5 BULK VOIDS(%)= | | 53.63 |
| STONE (nominal spread rate )= | 3.85 l/m^2 | 259.99 m^2/m^3 Appl (%) | | 84 |
| ELTdouble (mm)= | 12.2 VOIDSdouble(%)= | 48.9 | | |
| TRAFFIC (elv) = | 20000 | | | |
| Corrected Ball Penetration = | 5 | | | |
| Hardness of stone (10%FACT)= | 260 | | | |
| Embedment due to traffic (mm) = | 2.763 | | | |
| Layer thickness loss (dry roll)(mm) = | 1.1 | | | |
| Fractional binder displacement due to stone embedment (dry roll) = | | | 0.385771 | |
| Maximum allowable voids filled with binder (42% single, 55% double) = | | | 55 | |
| Wear due to traffic (mm) = | 0.835 | | | |
| Required texture depth (skid resistance)(mm) = | 0.7 | | | |
| Available void fraction = | 0.214 | | | |
| Minimum Void fraction = | 0.229 | | | |
| Maximum nominal quantity cold binder (normal life)(l/m^2) = | | 1.27 | | 1.835339 |
| Minimum nominal quantity cold binder (normal life)(l/m^2) = | | 1.36 | | 1.610681 |
| Texture depth of existing surface (mm) = | 1.55 | | | |
| Texture depth binder requirement (l/m2) = | PRETREAT | | | |
| Life expectancy (minimum application rate)(years) = | | 9.56 | 11.2765 | |

SEALDOUBLE(ELT,V)

| | | | | |
|---|---|---|---|---|
| ELT1(mm)= | 10.6 VOIDS(%)= | 57.5 BULK VOIDS(%)= | | 48.2 |
| STONE (nominal spread rate )= | 8.70 l/m^2 | 114.98 m^2/m^3 Appl (%) | | 100 |
| ELT2(mm)= | 4.47 VOIDS(%)= | 52.5 BULK VOIDS(%)= | | 53.63 |
| STONE (nominal spread rate )= | 3.85 l/m^2 | 259.99 m^2/m^3 Appl (%) | | 84 |
| ELTdouble (mm)= | 12.2 VOIDSdouble(%)= | 48.9 | | |
| TRAFFIC (elv) = | 20000 | | | |
| Corrected Ball Penetration = | 4 | | | |
| Hardness of stone (10%FACT)= | 260 | | | |
| Embedment due to traffic (mm) = | 2.548 | | | |
| Layer thickness loss (dry roll)(mm) = | 1.1 | | | |
| Fractional binder displacement due to stone embedment (dry roll) = | | | 0.385771 | |
| Maximum allowable voids filled with binder (42% single, 55% double) = | | | 55 | |
| Wear due to traffic (mm) = | 0.835 | | | |
| Required texture depth (skid resistance)(mm) = | 0.7 | | | |
| Available void fraction = | 0.237 | | | |
| Minimum Void fraction = | 0.249 | | | |
| Maximum nominal quantity cold binder (normal life)(l/m^2) = | | 1.41 | | 1.927103 |
| Minimum nominal quantity cold binder (normal life)(l/m^2) = | | 1.48 | | 1.706723 |
| Texture depth of existing surface (mm) = | 1.55 | | | |
| Texture depth binder requirement (l/m2) = | PRETREAT | | | |
| Life expectancy (minimum application rate)(years) = | | 9.66 | 11.24915 | |

SEALDOUBLE(ELT,V)

| | | | | | |
|---|---|---|---|---|---|
| ELT1(mm)= | 10.6 | VOIDS(%)= | 57.5 | BULK VOIDS(%)= | 48.2 |
| STONE (nominal spread rate )= | 8.70 l/m^2 | | 114.98 m^2/m^3 | Appl (%) | 100 |
| ELT2(mm)= | 4.47 | VOIDS(%)= | 52.5 | BULK VOIDS(%)= | 53.63 |
| STONE (nominal spread rate )= | 3.85 l/m^2 | | 259.99 m^2/m^3 | Appl (%) | 84 |
| ELTdouble (mm)= | 12.2 | VOIDSdouble(%)= | 48.9 | | |
| TRAFFIC (elv) = | 20000 | | | | |
| Corrected Ball Penetration = | 3 | | | | |
| Hardness of stone (10%FACT)= | 260 | | | | |
| Embedment due to traffic (mm) = | 2.271 | | | | |
| Layer thickness loss (dry roll)(mm) = | 1.1 | | | | |
| Fractional binder displacement due to stone embedment (dry roll) = | 0.385771 | | | | |
| Maximum allowable voids filled with binder (42% single, 55% double) = | 55 | | | | |
| Wear due to traffic (mm) = | 0.835 | | | | |
| Required texture depth (skid resistance)(mm) = | 0.7 | | | | |
| Available void fraction = | 0.271 | | | | |
| Minimum Void fraction = | 0.276 | | | | |
| Maximum nominal quantity cold binder (normal life)(l/m^2) = | 1.62 | | | | 2.064697 |
| Minimum nominal quantity cold binder (normal life)(l/m^2) = | 1.64 | | | | 1.838107 |
| Texture depth of existing surface (mm) = | 1.55 | | | | |
| Texture depth binder requirement (l/m2) = | PRETREAT | | | | |
| Life expectancy (minimum application rate)(years) = | 9.86 | | | 11.28889 | |

# DESIGNING A ONE-AND-A-THIRD SEAL USING MARGINAL AGGREGATE BY MEANS OF THE MODIFIED TRAY TEST

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**Dr Chris Semmelink** has extensive research experience in the field of road engineering. He has done research on Statistical Quality Assurance for Road Construction, Design of Surfacing Seals, Compactability and Compaction of Roadbuilding Materials, Determination of the Elastic and Shear Properties of Roadbuilding Materials (K-mould), Special Road Construction Techniques for Defence Force, Feasibility of Labour-intensive Construction Techniques, Impact Roller and Alkali-Aggregate Reaction in Concrete. He developed the Modified Tray Test as well as the Shakedown Bulk Density and Weighted Fractional Density Tests, designed the Transportek K-mould and developed the **COMPACT** software package. He was author or co-author of a substantial list of reports and papers on these subjects, which were presented both at local and international conferences. Presently he is mainly involved in solving problems experienced in the construction of roads.