KR LITHO PRETORIA

ANNUAL TRANSPORTATION CONVENTION
JAARLIKSE VERVOERWESEKONVENSIE

1991

CSIR Conference Centre, Pretoria
WNNR-konferensiesentrum, Pretoria

PAVEMENT ENGINEERING/
PLAVEISELINGENIEURSWESE

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COMPARISON BETWEEN FALLING WEIGHT DEFLECTOMETER (FWD) AND BENKELMAN BEAM DEFLECTION BASIN PARAMETERS AND BACK-CALCULATION OF LAYER MODULI

By

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SUMMARY

Many years of experience exist in South Africa on the use and interpretation of Benkelman beam type of road surface deflection measurements with the Road Surface Deflectometer (RSD), as well as depth deflection measurements with the use of the Multi-depth Deflectometer (MDD). These measurements are mainly associated with slow moving (creep or static) loads. The development however, of the impulse load deflection technology, which better reflects deflections at higher speeds (dynamic loading), allows comparative studies between creep and fast moving loads on pavements. This comparison is needed in order to better understand the effect of load duration on resilient behaviour of pavement systems. This study concentrates on a comparison between the deflection bowls (and its parameters) measured with the Impulse Deflectometer (IDM) and the Road Surface Deflectometer (RSD). The correlations of the deflection basin on granular pavements were higher than on cemented and asphalt base pavement structures. The IDM (impulse load) generally gives **lower** deflections than the RSD (creep load). It is believed, and it can be shown with rigorous theoretical analysis that the pavements dynamic characteristics, ie damping and inertia are the main reason for this behaviour. Further, poor correlations were found between the RSD and IDM back-calculated effective elastic moduli on asphalt and cemented base pavements. A better correlation, however, was found on granular base pavements. Although more detailed studies and refinement are necessary on this subject, the results presented here are viewed as a practical guide and are aimed to bridge the gap between creep load and impulse load technology on pavement structures in South Africa.

OPSOMMING

In Suid Afrika bestaan daar heelwat ondervinding met die gebruik en interpretering van Benkelman Balk tipe padoppervlak-defleksiemetings met die Padoppervlakdeflektometer (POD), asook diepte-defleksie metings met die gebruik van die Multidieptedeflektometers (MDD). Hierdie tipe metings is hoofsaaklik gedoen onder lae snelheidsmetings (kruip of staties). Die ontwikkeling egter van impulsbelasting-defleksietegnologie (dinamiese belasting) maak vergelykende studies tussen kruip en vinnig bewegende belasting op plaveisels egter nou moontlik. Hierdie vergelykings is nodig om die effek van tydsduur van belasting op die veerkragtigheidsgedrag van plaveiselsisteme beter te verstaan. Hierdie studie konsentreer op 'n vergelyking tussen die defleksie- komme (en parameters) soos gemeet met die Impulsdeflektometer (IDM) en die POD. Die korrelasies tussen die defleksiekomme op die granulêre plaveisels was hoër as diè gemeet op gesementeerde en asfaltkroolaag plaveisels. Die IDM

(impulsbelasting) lewer oor die algemeen **laer** defleksies as die POD (kruipbelasting). Die vermoede bestaan en kan deur teoreties korrekte metodes aangedui word dat die plaveisel se dinamiese eienskappe, nl demping en traagheid hierdie gedrag kan verklaar. Verder was daar swak korrelasies verkry tussen die POD en IDM terugberekende effektiewe elastisiteitsmoduli op asfalt en gesementeerdekroonlaag plaveisels. 'n Beter korrelasie is egter gevind vir die granulêre kroonlaag plaveisels. Alhoewel meer ge-detaileerde studies en verdere verfyning op hierdie onderwerp nodig is, word die resultate wat hier gegee word as 'n praktiese riglyn gegee en is gemik op die oorbrugging tussen kruip en impulsbelastingtegnologie vir plaveiselstrukture in Suid Afrika.

1 INTRODUCTION

Comparative measurements between creep (using modified Benkelman beam, called the Road Surface Deflectometer (RSD)) and impulse (fast moving) loads using the Falling Weight Deflectometer (Dynatest 8000 or Impulse Deflectometer (IDM) as its known in South Africa) were performed on six selected pavement structures, and includes the following:

- Asphalt base pavements (N1/22 and N3/4)
- High quality granular base pavements (Road P157-1 and Road 2212)
- Low quality granular base pavement (R25, (Road P95-1))
- Strongly cemented (block-cracked) base pavement (N4/1)

Both the IDM and RSD apparatus have advantages and disadvantages and therefore the following should be noted:

The IDM and RSD:

- are non-destructive test (NDT) apparatus
- can accurately measure the deflection basin (bowl)
- are computer driven and operated

The IDM :

- can measure relatively quickly
- has minimum traffic disruption

The RSD:

- is reasonably time consuming
- disrupts traffic more because of its relatively slow rate of measuring

The paper firstly discusses the effect of load on maximum deflection on a granular pavement (Road 2212) and then comparison between the deflection basin parameters of the various pavements as measured by the IDM and RSD. Finally,various back-calculated layer moduli are also discussed.

2 ROAD 2212 - BULTFONTEIN

2.1 Deflection versus load

At first an attempt was made to quantify the difference between maximum deflection at three different loads as was measured with the IDM and RSD. The Heavy Vehicle Simulator (HVS) site on Road 2212, near Bultfontein, was chosen to determine these differences. A layout of this granular base pavement structure at this site is shown in Figure 1. Figure 2 shows the maximum deflection against wheel load together with the regression constants for both the IDM and RSD measurements. The correlations were done on 184 data points per load for each set of measurements, and the standard deviations varied between 0.02 to 0.04 mm. The correlation coefficient (R-square) of the correlations for the IDM and RSD data were approximately 1.0 and 0.99, respectively. The figure indicates that the IDM deflections are **lower** than those of the RSD. The IDM deflection is approximately **65 % to 85 %** of the deflection of the RSD for a range of loading from 20 kN to 40 kN. The reason for the lower deflection from the IDM is related to the **damping and inertia** of the pavement system because impulse and moving wheel loads result in **lower stresses** in the pavement system and hence **lower deflections.** This behaviour can be shown by rigorous theoretical analysis (Lourens, 1991). The difference between IDM and RSD maximum deflection also **decreases** as the load increases for this pavement structure, which is believed to be related to the non-linearity or stress dependency and damping characteristics of the granular layer. In this case a possible interpretation is that the higher the stresses the higher the effective elastic moduli under both the creep and impulse loading, and that the damping (loss of energy) decreases with an increase in moduli under impact loading, hence the higher ratio (ie 85 %) in deflection under 40 kN loading.

3 BEHAVIOUR STATE ANALYSIS ON SELECTED PAVEMENTS.

A total of six pavements were used in the analysis reported in this paper. The N1/22, P157-1, R25 and N4/1 were tested twice, with a six monthly time interval. This was done to evaluate possible long term effect of traffic on the resilient deflection of the pavements, as defined by the various deflection basin parameters. The N3/4 was divided into three separate sections as the bitumen content of the asphalt base layer varied.

Full deflection basins were measured with both the IDM and RSD on these pavement structures. The deflections at certain distances on the deflection basin (0, 127, 305, 610, 915, 1200 and 1500 mm) were measured (an average of three readings) to correlate the IDM and RSD deflection bowls. This was done repetitively on every pavement structure to determine the variation in the deflection basin over a six monthly time period. In the results shown on Figures 4, 7, 9 and 11 and in Table 1, the A and B regression lines and ratio of deflection basin parameters were obtained with data measured on the same date and the lines C and D were obtained after a six month interval.

3.1 Behaviour state analysis on P157-1

Figure 3 shows the pavement structure on road P157-1 (to Jan Smuts), with the high quality granular base. The correlations between the IDM and RSD deflection basins are shown in Figure 5 together with the respective regression constants. The R-square varied between 0.84 and 0.94 for this pavement. The figure shows that the slopes and constants differ over the six month time period. Also, the higher the deflection (closer to the load) the more the regression lines converge between the RSD and IDM results. In this case for the maximum deflection, the IDM measures approximately 85 % of that of the RSD. The IDM/RSD ratios of all the deflection basin parameters are discussed in Paragraph 4 and Table 1 below.

3.2 Behaviour state analysis on Road R25 (P95-1)

Figure 4 shows the pavement structure on the R25 (P95-1) near Bronkhorstspruit, with the lower quality granular base. The correlations are also shown in Figure 5, together with the respective regression constants. The R-squared varied from 0.85 to 0.97 for this pavement, with a difference in the slopes. In this case the IDM measures approximately **94 %** of the maximum deflection of the RSD. Figure 4 also illustrates that on P157-1 and the R25 the higher the deflection (closer to the load) the more the slopes converge. The reason for this is at this stage not clear, but it may also relate to the in situ material state, stress dependencies, damping and inertia of these pavements, in particular those of the granular layers.

3.3 Behaviour state analysis on the N4/1

Figure 6 shows the pavement structure on the N4/1 near Pretoria, with the relatively strong cemented base. The correlations are shown in Figure 7 together with the respective regression constants. The R-square varied from 0.50 to 0.69 for this pavement, and is much lower than those found on the R25 and P157-1. The reason could be the existence of a fair amount of block cracking (degree 4, extent 5) on the test section. The figure further indicates that in this case the higher the deflection (closer to the load) the more the slopes of the different lines diverge. This may also be attributed to the block cracking and the dynamic characteristics of such a pavement. In this case the IDM measured approximately **66 %** to **88 %** of the RSD maximum deflection.

3.4 Behaviour state analysis on the N1/22

Figure 8 shows the pavement structure on the N1/22 near Pretoria, with the asphalt base. The correlations are shown in Figure 9 together with the respective regression constants. The R-square varied from 0.52 to 0.72 for this pavement. The correlations are slightly higher than on the N4/1 for this "very stiff" pavement but are also lower than those calculated for the R25 and P157-1. The slope between correlation lines also diverge with increased deflection for this pavement. It must, however, be emphasized that **no temperature correction** was done on the deflection data before comparison, because of lack of enough temperature/deflection data at the time of preparing this paper. It is believed that better correlations will result after such correction is introduced. Deflection data from any source on asphalt base pavements should not be interpreted without proper temperature corrections. Such practice will result in totally erroneous correlations and applications of deflection based rehabilitation design techniques (See De Beer, 1991).

3.5 Behaviour state analysis on the N3/4

Figure 10 shows the pavement structure on the N3/4 near Mooiriver, with an asphalt base with varying bitumen contents. The correlations are shown in Figure 11 together with the respective regression constants. The R-square varied from 0.76 to 0.82 for this pavement, and is much higher than on the

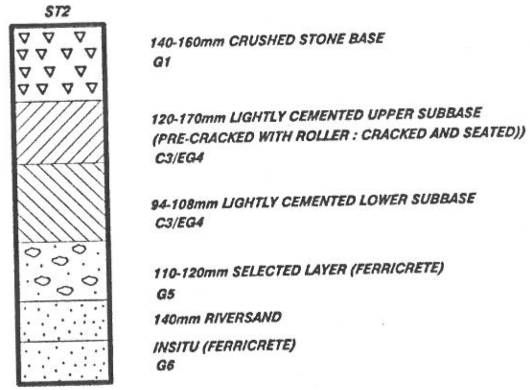


FIGURE 1

CONSTRUCTION DETAIL OF ROAD 2212 (BULTFONTEIN IN THE TRANSVAAL)

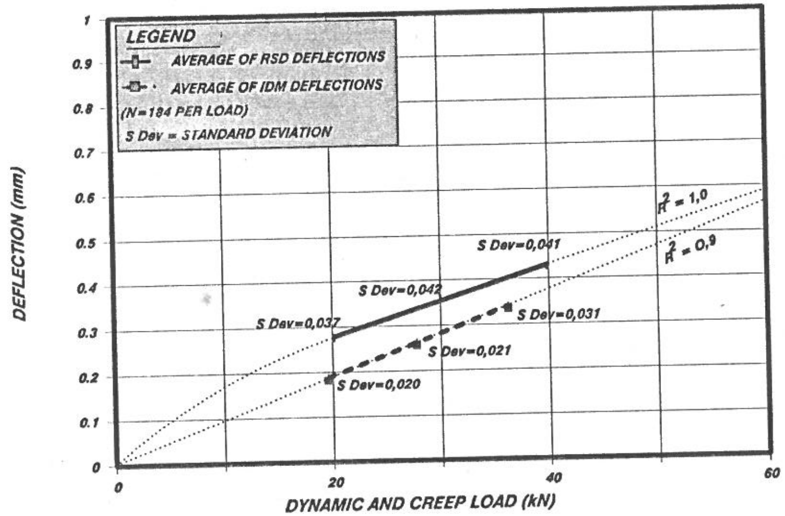


FIGURE 2

CORRELATION BETWEEN THE AVERAGE MAXIMUM SURFACE DEFLECTION AS MEASURED AT DIFFERENT WHEEL LOADS BY THE IDM AND RSD ON ROAD 2212 (BULTFONTEIN IN THE TRANSVAAL)

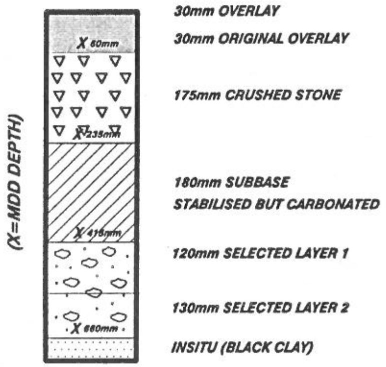


FIGURE 3
CONSTRUCTION DETAIL OF TEST SECTION ON P157-1 NEAR JAN SMUTS

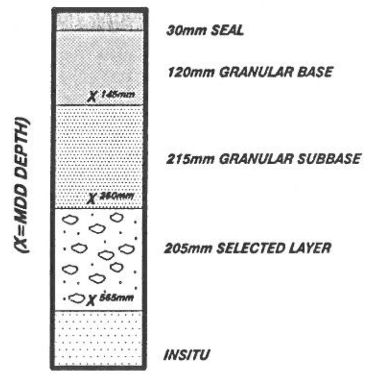


FIGURE 4
CONSTRUCTION DETAIL OF TEST SECTION ON THE R25 NEAR BRONKHORSTSPRUIT

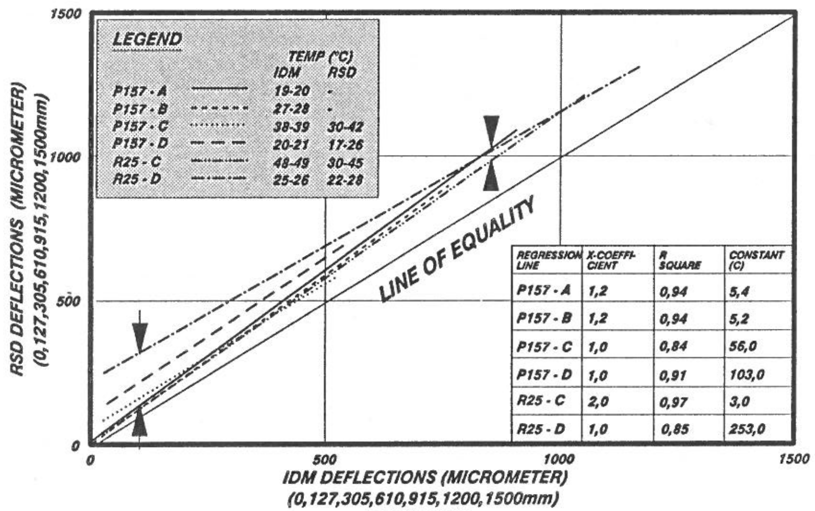


FIGURE 5

CORRELATION BETWEEN THE IDM AND RSD DEFLECTION BOWL ON GRANULAR BASE PAVEMENTS ON P157-1 AND R25

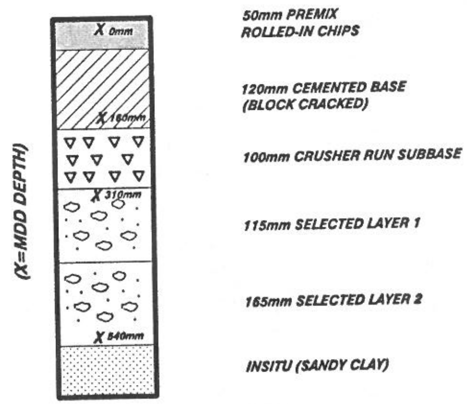


FIGURE 6
CONSTRUCTION DETAIL OF TEST SECTION ON THE N4/1 NEAR PRETORIA

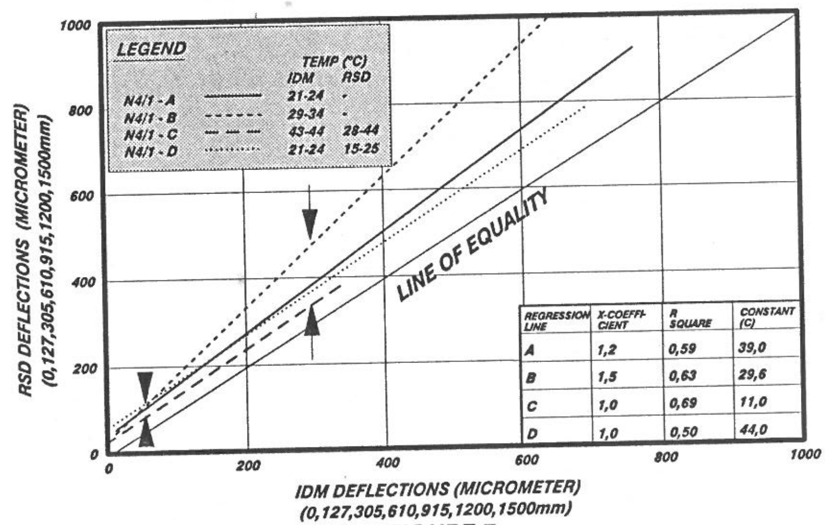


FIGURE 7

CORRELATION BETWEEN THE IDM AND RSD DEFLECTION BOWL ON A CEMENTED BASE PAVEMENT ON THE N4/1 (SOUTH)

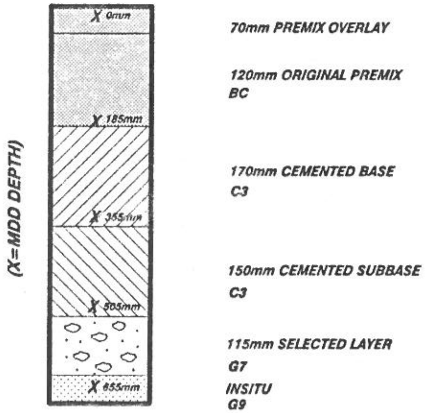
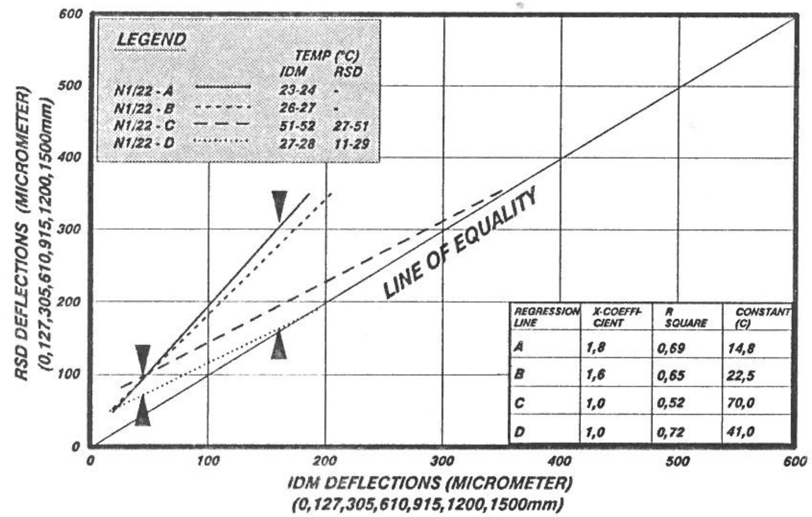


FIGURE 8

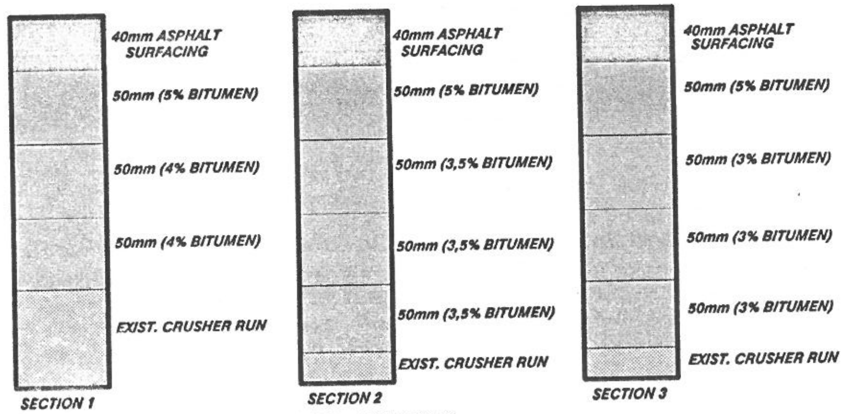
CONSTRUCTION DETAIL OF TEST SECTION ON THE N1/22 NEAR PRETORIA



REGRESSION LINE	X-COEFFI-CIENT	R SQUARE	CONSTANT (C)
A	1,8	0,69	14,8
B	1,6	0,65	22,5
C	1,0	0,52	70,0
D	1,0	0,72	41,0

FIGURE 9

CORRELATION BETWEEN THE IDM AND RSD DEFLECTION BOWL ON AN ASPHALT BASE PAVEMENT ON THE N1/22 (NORTH)

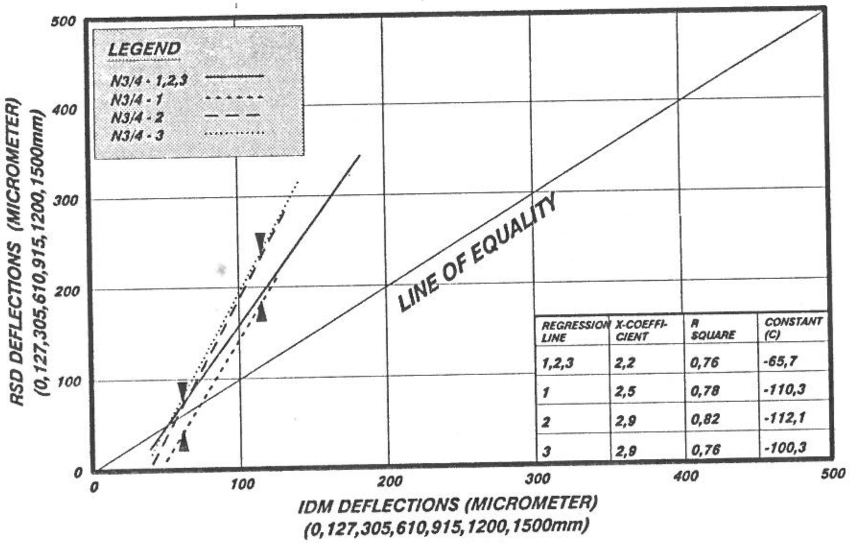


ASPHALT = SEMI GRADED

EXISTING CRUSHER RUN COMPACTED TO 95% MOD AASTHO

FIGURE 10

CONSTRUCTION DETAIL OF TEST SECTION ON THE N3/4 (MOOIRIVER)



REGRESSION LINE	X-COEFFI-CIENT	R SQUARE	CONSTANT (C)
1,2,3	2,2	0,76	-65,7
1	2,5	0,78	-110,3
2	2,9	0,82	-112,1
3	2,9	0,76	-100,3

FIGURE 11

CORRELATION BETWEEN THE IDM AND RSD DEFLECTION BOWL ON AN ASPHALT BASE PAVEMENT ON THE N3/4 NEAR MOOIRIVER

previous N1/22 (also an asphalt base pavement). The correlation lines diverge from each other with higher deflections (closer to the load) but not to the same degree as on the N1/22. Again, no temperature correction was done on these data, and may explain some of the differences in the measurements. According to the data the correlation lines converge with higher deflection on granular base pavements and diverge from each other with higher deflections on cemented and asphalt base (relatively stiff) pavement structures.

3.6 Discussion

In general, it can be concluded that the IDM measures lower deflections than the RSD on the investigated ranges of pavements. Differences, however, were also noticed, ie that for higher deflection levels the IDM and RSD are closer on granular pavements, but further apart for cemented and asphalt base pavements. For asphalt base pavements, however, temperature corrections could improve the situation. At this stage the obtained relationships are viewed as practical guidelines, and it should be incorporated into deflection based rehabilitation design in that the deflection bowl parameters should be standardized, ie converted from IDM to RSD, or visa versa, depending on the selected criteria for rehabilitation design. For this purpose the following tentative conversion factors for **maximum deflection** are recommended in Table 1:

TABLE 1 Conversion factor from RSD maximum deflection to IDM deflection

TYPE OF BASE	RATIO (RANGE)	RATIO (AVERAGE)
GRANULAR*	0.81-0.99	0.90
CEMENTED ** (BLOCK CRACKED)	0.66-0.83	0.77
ASPHALT***	0.49-0.82	0.61

* Surface treatment (15 mm) up to 50 mm asphalt surfacing
** 50 mm to 60 mm asphalt surfacing
*** Temperature range: 11 to 52 degrees celcius

| EXAMPLE: IDM=Average Ratio*RSD=Factor*RSD
| Cemented base: Factor=0.77=>IDM=0.77*RSD
| RSD=0.75 mm=>IDM=0.77*0.75=0.58 mm

4 BEHAVIOUR STATE ANALYSIS USING DEFLECTION BASIN PARAMETERS

Deflection basin parameters are used to improve the estimation of effective elastic moduli for the identified material state and behaviour state of pavements (see Horak et al, 1989). An average value for each of the different deflection basin parameters was calculated according to the respective length of the section for each pavement. The ratios between the IDM and RSD deflection basin parameters were calculated on all the pavements discussed before, and are shown in Tables 2 to 7. These tables show that the ratios differ from parameter to parameter as well as from pavement to pavement. The ratio between all the parameters also varies somewhat when measured over a six monthly time period. The detail of the correlations can be found elsewhere (Lacante et al, 1989a-f and 1990a).

TABLE 2 - RATIO BETWEEN THE DEFLECTION BASIN PARAMETERS AS MEASURED BY THE IDM AND RSD ON P157-1 NEAR JAN SMUTS

TEST	MAX. DEF	SD	SPR	HE	ESUBG	AAS-THO	BCI	BDI	RC	SCI	F1
A	0,87	0,90	1,64	0,89	1,14	0,62	0,86	0,91	1,20	0,87	1,15
B	0,87	0,91	1,64	0,89	1,16	0,63	0,84	0,88	1,13	0,88	1,23
C	0,89	0,98	0,94	0,69	0,94	3,83	0,74	0,86	9,28	1,18	1,67
D	0,81	1,14	0,90	0,50	1,16	7,06	0,49	0,43	7,40	1,68	2,61

TABLE 3 - RATIO BETWEEN THE DEFLECTION BASIN PARAMETERS AS MEASURED BY THE IDM AND RSD ON THE R25 (P95-1) NEAR BRONKHORSTSPRUIT

TEST	MAX. DEF	SD	SPR	HE	ESUBG	AAS-THO	BCI	BDI	RC	SCI	F1
C	0,89	0,63	0,94	0,81	0,81	2,06	0,87	0,73	22,77	0,95	1,32
D	0,99	1,09	0,81	0,39	0,73	4,34	0,42	0,95	4,34	2,59	3,64

TABLE 4 - RATIO BETWEEN THE DEFLECTION BASIN PARAMETERS AS MEASURED BY THE IDM AND RSD ON THE N4/1 NEAR PRETORIA

TEST	MAX. DEF	SD	SPR	HE	ESUBG	AAS-THO	BCI	BDI	RC	SCI	F1
A	0,79	1,00	0,86	0,72	1,36	0,56	0,66	0,82	0,42	1,00	1,67
B	0,66	0,88	0,86	0,61	1,68	0,65	0,55	0,65	0,55	0,92	2,00
C	0,83	0,95	1,10	1,11	0,67	1,63	0,66	1,36		0,74	1,05
D	0,80	0,75	1,09	1,01	0,69	1,93	0,84	1,00	22,28	0,64	0,79

TABLE 5 - RATIO BETWEEN THE DEFLECTION BASIN PARAMETERS AS MEASURED BY THE IDM AND RSD ON THE N1/22 NEAR PRETORIA

TEST	MAX. DEF	SD	SPR	HE	ESUBG	AAS-THO	BCI	BDI	RC	SCI	F1
A	0,58	0,74	0,94	0,71	1,81	1,30	0,55	0,74	1,22	0,74	-
B	0,52	0,62	1,03	0,85	1,93	1,32	0,52	0,65	3,38	0,59	-
C	0,79	1,26	0,96	0,30	0,86	0,04	1,05	1,13	0,63	1,37	-
D	0,82	1,58	1,09	0,64	0,88	3,10	1,09	1,57	3,45	0,91	-

TABLE 6 - RATIO BETWEEN THE DEFLECTION BASIN PARAMETERS AS MEASURED BY THE IDM AND RSD ON THE N1/23 NEAR RICHMOND

TEST	MAX. DEF	SD	SPR	HE	ESUBG	AAS-THO	BCI	BDI	RC	SCI	F1
342A2	0,95	1,06	0,91	0,48	2,25	1,65	0,63	1,00	0,47	1,06	-

TABLE 7 - RATIO BETWEEN THE DEFLECTION BASIN PARAMETERS AS MEASURED BY THE IDM AND RSD ON THE N3/4 NEAR MOOIRIVER

TEST	MAX. DEF	SD	SPR	HE	ESUBG	AASTHO	BCI	BDI	RC	SCI	F1
1	0,57	0,29	1,36	2,40	0,90	0,68	0,78	0,45	-	0,19	-
2	0,50	0,28	1,27	2,00	1,27	0,68	0,57	0,34	-	0,22	-
3	0,49	0,28	1,27	1,90	1,42	0,79	0,48	0,31	-	0,24	-

With respect to Tables 2 to 7, the following explanations are given:

Ratio = average IDM value / average RSD value

ESUBG = E-MODULI FOR SUBGRADE
AASTHO = E-MODULI OF SUBGRADE
BCI = BASE CURVATURE INDEX
RC = RADIUS OF CURVATURE
MAX. DEF = MAXIMUM DEFLECTION
SPR = SPREADABILITY

F1 = SHAPE FACTOR
HE = EQUIVALENT LAYER STRENGTH THICKNESS
BDI = BASE DAMAGE INDEX
SCI = SURFACE CURVATURE INDEX
SD = SLOPE OF DEFLECTION

5 BACK-ANALYSES OF ELASTIC LAYER MODULI

The technique used to obtain the elastic moduli (E-moduli) is known as "Back-analyses". It involves computing by an iterative procedure, a theoretical deflection basin which very closely matches the measured one. One of the main problems facing the engineer is not only the structural properties of the various pavement layers, but also to know the behaviour of the pavement structure and the interaction of the various pavement layers under moving loads. This need has led to the development of various testing techniques and data evaluation procedures. Multidepth deflectometers were installed on P157-1, the R25, N4/1 and N1/22 to do a comparative study between the different back-calculation procedures and methods. The IDME program (ELMOD, 1987) seems favourable for analyses of IDM data on granular base pavements if compared to MDD back-calculated E-moduli with CHEV15TF. Therefore only the IDME and CHEV15TF results are covered in this paper. For more detail about the other available software programmes such as ISSEM4, MODBISAR and MODULUS, see Lacante et al, (1990b and c, and Balmaceda et al, (1990).

5.1 Comparison between E-moduli (CEV15TF and ELMOD (IDME)

One of the aims of this paper is also to put the effective elastic moduli calculated by IDME into perspective to existing procedures such as CHEV15. IDM data were collected to back-calculate effective elastic moduli with the ELMOD program, and RSD and MDD data were collected on P157-1, the R25, the N4/1 and the N1/22 to calculate effective elastic moduli with CHEV15TF. All the possible user defined selections in ELMOD, such as combined granular and asphalt, cemented and asphalt layers, etc, were used to clear uncertainties in the interpretation of input data.

According to the MDD and IDM the E-moduli varied from 252 to 280 MPa and from 398 to 413 MPa respectively for the base layer, from 135 to 137 MPa and from 112 to 138 MPa for the subbase and from 73 to 86 MPa and 49 MPa for the selected layer on the R25. The ratio thus varies from 0.81 to 0.96 for this granular base pavement. As moduli vary in practice there is no significant difference between the E-moduli for the base, subbase and in-situ material for this pavement. See Figure 13 for

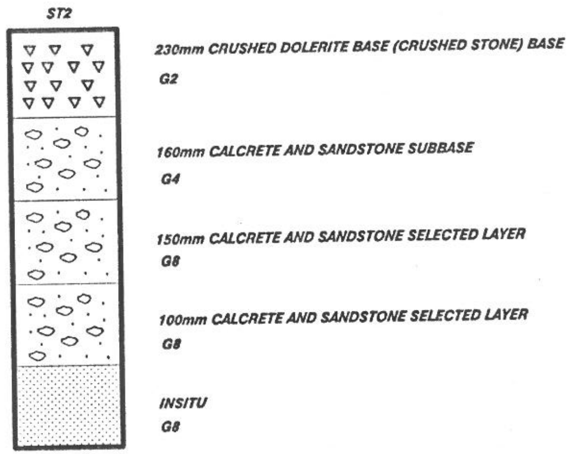


FIGURE 12
CONSTRUCTION DETAIL OF TEST SECTION ON THE N1/23 NEAR RICHMOND

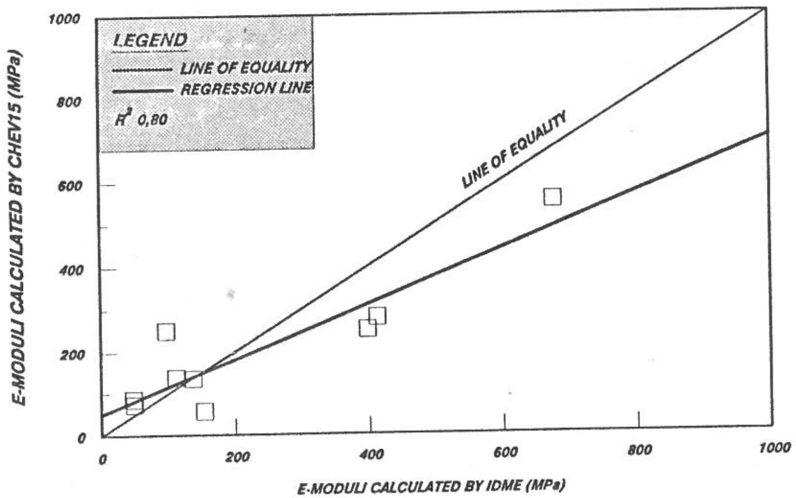


FIGURE 13
CORRELATIONS BETWEEN EFFECTIVE E-MODULI AS CALCULATED BY CHEV15 AND IDME ON GRANULAR PAVEMENT LAYERS

the graphical representation and regression constants between IDM (IDME) and MDD (CHEV15TF) back-calculated effective elastic moduli for granular base pavements (P157-1 and R25). The IDM overestimate the base and subbase E-moduli and underestimate the in-situ E-moduli. The ratio between E-moduli on asphalt base pavements varied from 0.01 to 1.54, indicating that the IDM gave higher E-moduli in some and lower E-moduli in other instances. The ratio between E-moduli thus varied much more on asphalt and cemented base pavements than on granular base pavements.

6 SUMMARY AND CONCLUSIONS

This paper summarises the most recent detailed comparative study on seven different pavements between the creep loading deflections measured with the Road Surface Deflectometer (RSD), and the impulse (dynamic) load deflections measured with the Impulse Deflection Meter (IDM). The types of pavements investigated varied between granular, asphalt and strongly cemented base layers. The results in this paper show that there can be a significant difference between the IDM and the RSD measured deflection basin (bowl) parameters. For all seven different pavements investigated, the IDM deflections **(impulse loading)** were **lower** than those measured with the RSD **(creep loading)**. It is believed that this difference is directly related to the **dynamic characteristics** of the pavement materials, and that **material damping** and **inertia effects** causes **lower stress levels** than creep loading, hence the lower deflections under impact or impulse loading. The highest correlations between the IDM and RSD deflection basin were found on the granular base pavements. The average ratio between IDM/RSD maximum deflection varied between 0.61 and 0.90 for the pavements investigated (see Table 1). The ratios between the various other deflection basin parameters for six of the pavements investigated were calculated (see Tables 1 to 7), and is given as a practical guide towards improved deflection based rehabilitation design in South Africa. Limited data on the deflection basin parameters also indicated a variation over a six month period.

The correlation between back-calculated effective elastic moduli (IDME - ELMOD and MDD - CHEV15TF) seems favourable on granular base pavements (P157-1 and the R25), but not very good at this stage, for asphalt and cemented base pavements. It should, however, be recognised that there will be differences in the back-calculated moduli because of the difference between the IDM impulse load deflection from a single semi-rigid plate, and the RSD/MDD creep load deflection under dual elastic wheel loading. Further, the IDM and RSD measure on the pavement's surface and the MDD's in depth, and a broader survey is needed to determine better correlations between IDM and RSD/MDD type measurements, and with higher confidence (See Lacante et al, 1989a,b).

Although the IDM and RSD measure two different deflection basins, the IDM can be used with great confidence in pavement analyses. The IDM and RSD deflection basins (deflection basin parameters) should however be carefully converted and interpreted before use in deflection based rehabilitation design.

7 RECOMMENDATIONS

The following follow-up research is strongly recommended:

- Development of temperature correction factors for deflection on asphalt based pavements in South Africa. Current research at the DRTT is already underway in this respect.
- Extension of theoretical and pavement modelling aspects to include the effects of pavement dynamics, ie material damping and inertia. Current three dimensional non-linear dynamic and static modelling techniques are available at DRTT to back-calculate material damping from MDD measured deflections. Limited work has also been started at DRTT in this respect.
- The ideal would be to develop a software package for the back-calculation of effective elastic layer moduli locally, possibly including effects of the dynamic characteristics of pavement materials. Such a package should be based on South African conditions and experience, and will enhance the use of the IDM technology in order to assist the engineer with deflection based rehabilitation studies and material properties on South African pavements.

8 ACKNOWLEDGEMENTS

The South African Roads Board and the Department of Transport (DOT) is thanked for their financial support for this project under RDAC NUMBER: 88/025. The Division Director of the Division of Transport and Road Technology (DRTT) is also thanked for permission to publish this paper.

9 REFERENCES

LACANTE, S C, HORAK E and DE BEER, M (1989a). VERBAND TUSSEN DIE DEFLEKSIE-METINGS VAN DIE IDM, RSD EN MDD OP SEKSIE 339A4 OP GEBREEKTEKLIP KROONLAE (G1) OP PAD 2212 (BULTFONTEIN). Transportek unpublished report, I/FP/12/89.

LACANTE, S C, HORAK E and DE BEER, M (1989b). ANALISE VAN DIE DEFLEKSIEOPNAME VAN DIE IDM, RSD EN MDD OP DIEP GRANULêRE PLAVEISELS OP NASIONALE ROETE (N1) TUSSEN RICHMOND EN DRIE SUSTERS (TOETSSEKSIE 342A2). Transportek unpublished report, I/FP/17/89.

LACANTE, S C, and HORAK E(1989c). EVALUATION OF DEFLECTION SURVEY ON GRANULAR PAVEMENT STRUCTURES BETWEEN RICHMOND AND THREE SISTERS (N1/23). Transportek unpublished report, I/FP/20/89.

LACANTE, S C, HORAK E and DE BEER, M(1989d). REPORT AND RECOMMENDATIONS ON CORRELATIONS BETWEEN IDM AND RSD DEFLECTION BASINS ON SEVERAL PAVEMENT STRUCTURES IN THE TRANSVAAL, NATAL AND CAPE PROVINCE (NOVEMBER 1989). Transportek unpublished report, I/FP/27/89.

LACANTE, S C, HORAK E and DE BEER, M(1989e). EVALUATION OF DEFLECTION SURVEY ON A FULL DEPTH EXPERIMENTAL ASPHALT BASE PAVEMENT BETWEEN KILDARE INTER-CHANGE AND MOOIRIVER (N3/4). Transportek unpublished report, I/FP/22/89.

LACANTE, S C, HORAK E and DE BEER, M(1990a). REPORT AND EVALUATION OF SOFTWARE FOR BACKANALISYS PROCEDURES. Transportek unpublished report, I/FP/1/90.

LACANTE, S C, HORAK E and DE BEER, M(1990b). SOFTWARE EVALUATION FOR BACKANALYSIS OF ELASTIC MODULI PROCEDURES SUCH AS CHEV15 AND IDME. Transportek unpublished report, I/FP/19/90.

LACANTE, S C, HORAK E and DE BEER, M(1990c). EVALUATION OF DEFLECTION SURVEY AND THE LONG TERM EFFECT ON SEVERAL PAVEMENT STRUCTURES IN THE TRANSVAAL (N1/22, N4/1, P157/1 AND R25). Transportek unpublished report, I/FP/2/90.

BALMACEDA, LACANTE, S C, HORAK E and DE BEER, M. SOFTWARE EVALUATION FOR BACKCALCULATION OF EFFECTIVE ELASTIC MODULI PROCEDURES - ISSEM4, MODBISAR, MODULUS, IDME AND CHEF15. Transportek unpublished report, I/FP/9/90.

HORAK E, MAREE J N and VAN WIJK A (1989 ATC). PROCEDURES FOR USING IMPULSE DEFLECTION (IDM) MEASUREMENTS IN THE STRUCTURAL EVALUATION OF PAVEMENTS. DRTT, CSIR PO BOX 395, PRETORIA. 0001.

DE BEER, M (1991). PAVEMENT RESPONSE MEASURING SYSTEM. Paper prepared for the 2nd International Symposium on Pavement Response Monitoring Systems for Roads and Air Fields, 6 to 9 September 1991, Hanover, New Hampshire, USA.

LOURENS, J P (1991). NONLINEAR DYNAMIC ANALYSIS OF ROAD PAVEMENTS. Interim Report IR 90/030/1, South African Roads Board, RDAC, January 1991.

ELMOD/ELCON (1987). EVALUATION OF LAYER MODULI AND OVERLAY DESIGN. User's Manual for ELMOD on IBM compatible PC's, November 1987, Version 3.0, Dynatest Consulting, Inc.