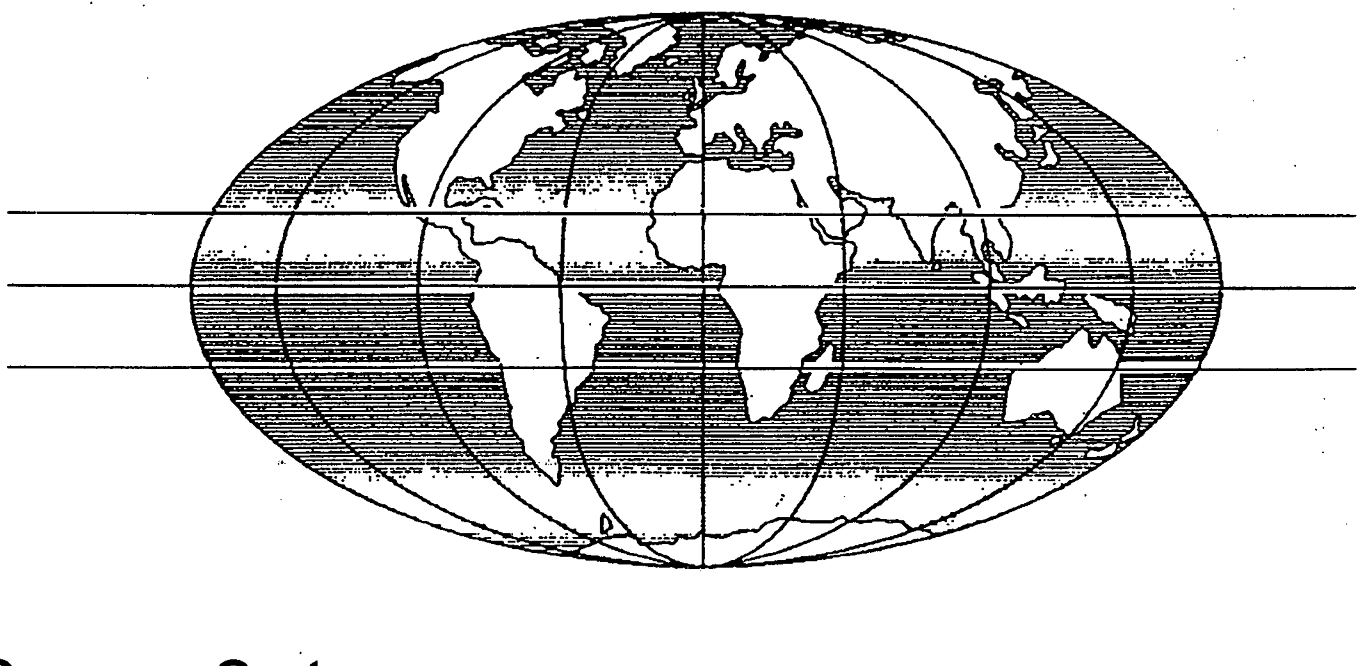
TRANSPORT RESEARCH LABORATORY

ODA

Reprint

TITLE **Reflection crack propagation in asphaltic concrete overlays in Malaysia**

by G Morosiuk, W G Ford
and Abdul Mutalif



Overseas Centre
Transport Research Laboratory
Crowthorne Berkshire United Kingdom

MOROSIUK, G, W G FORD and A MUTALIF, 1992. Reflection crack propagation in asphaltic concrete overlays in Malaysia. In: **Proceedings of the Seventh REAAA Conference, Singapore, 22-26 June 1992.**

REFLECTION CRACK PROPAGATION IN ASPHALTIC CONCRETE OVERLAYS IN MALAYSIA

Dr G Morosiuk
Transport and Road Research Laboratory
United Kingdom

W G Ford
Transport and Road Research Laboratory
United Kingdom

Abdul Mutalif
Institute of Training and Research
Malaysia

ABSTRACT

This paper describes the performance of 40mm thick asphaltic concrete overlays used to rehabilitate paved roads in Peninsular Malaysia. In the study one-kilometre lengths of road were surveyed in terms of pavement condition and strength prior to being overlaid, and their deterioration was monitored after overlay. A model has been developed that predicts the effectiveness of the 40mm overlays as a rehabilitation technique based on the intensity of cracking and pavement strength prior to overlay and the commercial traffic flow after overlay. The results show that the overlays deteriorate by reflection cracking and that they are, as a result, only partially successful in preventing cracks propagating through the overlay even on areas of low crack intensity. This study was carried out under a joint cooperative research programme between the Transport and Road Research Laboratory (TRRL) of the United Kingdom and the Jabatan Kerja Raya (JKR) of Malaysia.

1.0 INTRODUCTION

The paved road network of Peninsular Malaysia has been constructed over a period of 30-40 years and at present comprises approximately 22,000 kilometres. The geometric and pavement design standards and traffic levels across the network are wide ranging. Current overlay construction in Malaysia falls broadly into two categories. Firstly, overlays are constructed mainly by the State authorities to a thickness of 40mm irrespective of the structural capacity of the existing road pavement or the future traffic loading. Secondly, overlays are constructed to a designed thickness using the present JKR method which is a modified version of the Shell design method (Shell International Petroleum, 1978). In both cases asphaltic concrete is used as specified in the JKR manual on pavement design (Jabatan Kerja Raya, 1985).

A research project was designed so that the performance of both types of overlay could be evaluated and related to the structural strength and surface condition of the existing road pavement, the design traffic and the properties of the new surfacing material.

Monitoring of the performance of new asphaltic concrete overlays began in mid-1988. Cracks started to appear in the 40mm overlays within a relatively short period of time whereas the designed overlays, generally constructed to a thickness of at least 100mm, have shown little sign of deterioration over a three year period.

This paper reports the performance of the 40mm thick overlays between mid-1988 and mid-1991.

2.0 EXPERIMENTAL DESIGN

In order to evaluate how effective the 40mm overlays were in rehabilitating existing cracked asphaltic concrete surfacings, a factorial experimental design was used, the variables being pavement strength, pavement condition and traffic level. The condition of the road pavement on each site was quantified in terms of cracking, and the strength of the sites was assessed using pavement deflection tests. The traffic volumes were obtained from classified traffic counts conducted by the Highway Planning Unit (HPU) of the Ministry of Works.

The performance of the overlays on ten one-kilometre sites, located on 2-lane roads throughout Peninsular Malaysia, was assessed. Each site, in both directions of travel, was sub-divided into 100 ten-metre long test areas, or blocks, each block being the width of the lane. The performance of each block was then treated as a discrete unit for the purpose of measurement and analysis, and was characterised by its surface condition and strength before overlay. Regular surveys were carried out after construction to monitor the progression of deterioration of each block.

The overlays were constructed using 14mm nominal maximum sized aggregate, asphaltic concrete wearing course. The JKR specifications for this type of overlay are given in Table 1.

Table 1 JKR Specifications - 14mm A.C. Wearing Course

Sieve size (mm)	Specification (per cent passing)
20.0	100
12.5	78 - 100
10.0	68 - 90
5.0	52 - 72
2.4	38 - 58
0.6	20 - 36
0.3	12 - 25
0.150	7 - 16
0.075	4 - 8
Bitumen content (%)	5.5 - 7.0
Voids in mix (%)	3 - 5
Voids filled with bitumen (%)	76 - 82
Stability (Kg)	>500
Flow (mm)	2 - 4

3.0 PRE-CONSTRUCTION AND POST-CONSTRUCTION MEASUREMENTS

Lengths of road that were not typical of a site (e.g. in the vicinity of a culvert, bridge, etc) were not included in the study. Generally, therefore, less than the possible maximum of 200 blocks (100 in each direction) were monitored on a site.

Deflection tests were carried out at 40-metre intervals on the border of two adjacent blocks in a set of four consecutive blocks. Only the two blocks adjacent to deflection measurements (a maximum of 100 per site) were used in the analysis described in the paper.

The construction techniques were not under investigation in this study and therefore were not monitored. Core samples, however, were taken from the sites after construction and tested for the binder content and grading of the new material.

If the binder content was excessively high and areas on the site were visibly 'rich' in bitumen, then the appropriate blocks were removed from the study. The range of gradings of all the cores taken from the ten sites, plotted in Figure 1, shows that generally the gradings of the material conformed to the JKR specifications.

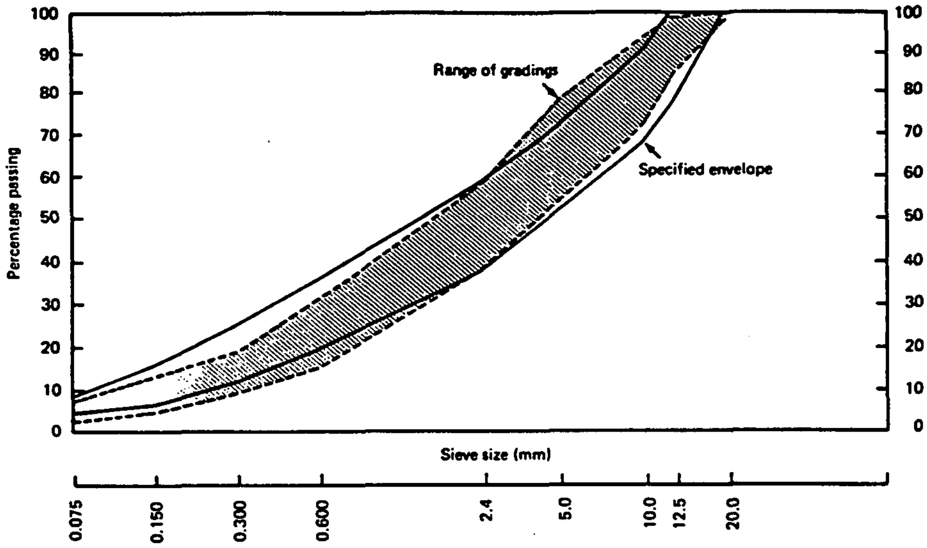


Fig.1 Aggregate grading of asphaltic concrete wearing course

3.1 Cracking

The intensity of the cracking in each block was recorded using the following codes.

0 No cracks
1 Single crack
2 More than one crack - not connected
3 More than one crack - interconnected
4 Crocodile cracking

The intensity of cracking on each site prior to overlay (Initial Crack Intensity - ICI) is shown in Table 2.

3.2 Deflection Measurements

Pavement deflection tests were carried out on the sites with the Falling Weight Deflectometer (FWD) at 40-metre intervals in the vergeside wheelpath for both directions of travel. These tests were conducted prior to overlay and at regular intervals after overlay. The deflections were corrected to a standard pressure of 700 KPa and a temperature of 40 deg C.

All the overlays were of the same thickness resulting in the deflections after overlay being reduced by a similar amount (approximately 20 per cent). Therefore only the deflections prior to overlay (initial deflections) are used in the analysis described below. The range and mean of the central deflections prior to overlay for each site are given in Table 2.

3.3 Traffic Volumes

The classified traffic counts published by the HPU are for a 16 hour day between 0600 hrs and 2200 hrs. Traffic surveys carried out by the National Axle Load Study (Public Works Department, Malaysia, 1987) showed that the 16 hour figures accounted for approximately 71 per cent of the 24 hour flows for the heavy goods class and 86 per cent for all the other classes of vehicles. These factors have been used to estimate the 24 hour traffic flows.

In this study medium and heavy goods vehicles and buses have been classified as commercial vehicles. The unidirectional average daily number of commercial vehicles for each site is given in Table 2.

Table 2 **Site Details**

Site No.	Average Daily Commercial Vehicles	Initial Central Deflection (mm)			Initial Crack Intensity (ICI) (Number of blocks)					
		Min	Max	Mean	0	1	2	3	4	Total
1	230	0.443	2.089	0.884	9	20	9	15	40	93
2	530	0.351	1.171	0.665	38	18	3	9	27	95
3	703	1.018	2.420	1.384	0	4	0	33	36	73
4	123	0.764	3.950	2.240	22	4	3	40	29	98
5	2623	0.308	2.011	1.135	0	3	0	23	74	100
6	1827	0.295	1.564	0.748	4	3	14	44	33	98
7	2305	0.223	0.862	0.469	16	17	7	26	14	80
8	1472	0.365	1.174	0.723	1	1	0	10	65	77
9	1247	0.390	2.420	1.322	9	8	6	43	32	98
10	1351	0.163	0.937	0.453	13	22	12	35	10	92
Total					112	100	54	278	360	904

4.0 DETERIORATION OF THE OVERLAYS

The regular surface condition surveys conducted after construction revealed that the overlays deteriorated in the form of cracking. The cracks which appeared in the new overlays were investigated to determine the cause of distress. The site investigations were conducted by coring through cracks that had appeared in the pavement surface. These cores confirmed that the cracks had reflected through the new overlays from the old surface. Blocks with no cracks (ICI = 0) were not included in the analysis discussed in this paper as their deterioration was not by reflection cracking.

The estimates of the effects of the different variables contributing to reflection cracking were assessed by fitting a model using the computer program GLIM (Baker and Nelder, 1978). The assumption in the model is that at some time, T, after the construction of an overlay, a number of blocks on a site will have cracked. In general linear modelling, this is a binomial error structure. The probability of cracking, P, must lie between 0 and 1 and a graph of P against T is 'S' shaped, where P is dependent on some function of traffic, deflection and initial crack intensity (ICI).

The cumulative number of commercial vehicles (CV) was used as a descriptor of the time to cracking. In this analysis, cracks had to extend over at least 10 per cent of the area of a block for a block to be deemed to have cracked. The model that best described the probability of cracking is given below.

$$P/(1-P) = \exp(a + bCV + cDEF) \qquad \ldots\ldots\ (1)$$

where P = Probability of cracking
CV = Cumulative commercial vehicles (thousands) to cracking
DEF = Central FWD deflection (mm) prior to overlay

a = -4.0	b = 0.00167	c = 1.83	for ICI = 1
a = -3.7	b = 0.00182	c = 1.67	for ICI = 2
a = -2.3	b = 0.00210	c = 0.81	for ICI = 3
a = -2.2	b = 0.00202	c = 1.10	for ICI = 4

The estimates of the constant 'a' and coefficients 'b' and 'c' are variable and depend on the intensity of cracking on the existing surface prior to overlay (ICI). The accuracy of the model, obtained by comparing the predicted number of blocks cracked after the passage of any number of commercial vehicles with the actual number observed during the study, is given by the R^2 value. The R^2 value for equation (1) was 0.71.

Figure 2 illustrates the probability of reflection cracking with CV for three categories of cracking and three levels of deflection. This figure shows that the onset of reflection cracking is rapid and also illustrates its dependency on ICI and initial deflection. At the lowest intensity of cracking (ICI = 1), 50 per cent of the blocks had cracked after the passage of almost 2 million commercial vehicles for a deflection of 0.5mm and after 0.75 million for a deflection of 1.5mm. At ICI = 3, 50 per cent of the blocks had cracked after only 0.9 and 0.5 million commercial vehicles for deflections of 0.5mm and 1.5mm respectively.

Figure 3 illustrates the probability of reflection cracking for three categories or road pavement strength, each category covering the four ICI's. At low deflections there is a distinct difference between blocks with an ICI of either 1 or 2 and the ones with an ICI of either 3 or 4. As the deflections increase the difference between the two groups becomes less prominent until there is a gradual progression from ICI = 1 to ICI = 4, as illustrated at deflections of 1.5mm.

For example, at a deflection of 0.5mm and after one million commercial vehicles, approximately 20 and 25 per cent of blocks had cracked with an ICI of 1 and 2 respectively whereas 57 and 60 per cent had cracked with an ICI of 3 and 4 respectively. For a deflection of 1.5mm the respective number of blocks that had cracked was 60, 65, 75 and 80 per cent.

The average daily flow for the ten sites was 1250 commercial vehicles. For this level of traffic, 50 per cent of the blocks with an ICI of 3 or 4 will have cracked within two years on roads with a relatively low deflection of 0.5mm prior to overlay. On roads with an initial deflection of 1.0mm (average for the ten sites), over 60 per cent of these blocks will have cracked within two years.

5.0 CONCLUSIONS

This study has investigated the effectiveness of 40mm thick asphaltic concrete overlays, over a three year period, as a means of rehabilitating cracked paved road surfacings on roads with traffic flows ranging from 100 to over 2500 commercial vehicles per lane per day. The results of this investigation have shown that cracks in the existing surface reflected through the new overlay in a relatively short period of time.

The rate at which reflection cracks formed depended on the intensity of cracking and the magnitude of the pavement deflection prior to overlay, and the cumulative flow of commercial vehicles after construction.

The effect of ICI on the probability of cracking is more distinct on roads with low deflections. Where deflections were high the blocks cracked within a short period of time, with the effect of ICI being less prominent.

The results of this study show that the use of 40mm overlays to rehabilitate roads with interconnected cracks (ICI = 3 or 4) is ineffective. On roads with a daily traffic flow in excess of 1250 commercial vehicles, over 50 per cent of the blocks will crack within two years, even at low deflections. For roads with deflections over 1.0mm, the 40mm overlays are similarly ineffective irrespective of the level of cracking.

It is therefore recommended that 40mm thick overlays are not used on roads with interconnected cracks unless the cracks are treated prior to overlay. Similarly all cracks should be treated prior to overlay if the initial deflections exceed 1.0mm.

6.0 ACKNOWLEDGEMENTS

This study was carried out under a joint cooperative research programme between the Transport and Road Research Laboratory (TRRL) of the United Kingdom and the Jabatan Kerja Raya (JKR) of Malaysia.

The authors would like to thank the Director of the JKR for permission to publish the paper.

The work described in this paper forms part of the research programme of the Overseas Unit (Unit Head: Mr J S Yerrell) of the TRRL carried out on behalf of the Overseas Development Administration. Any views expressed are not necessarily those of the Administration, the Department of Transport or the JKR. The paper is published by permission of the Chief Executive of the TRRL.

7.0 REFERENCES

BAKER, R J and J A NELDER (1978). The GLIM system. Numberical Algorithms Group, Oxford.

JABATAN KERJA RAYA, (1985). Manual on Pavement Design. Arahan Teknik (Jalan) 5/85.

PUBLIC WORKS DEPARTMENT, MALAYSIA, (1987). Malaysian National Axle Load Study.

SHELL INTERNATIONAL PETROLEUM CO. LTD, (1978). Shell Pavement Design Manual, London.

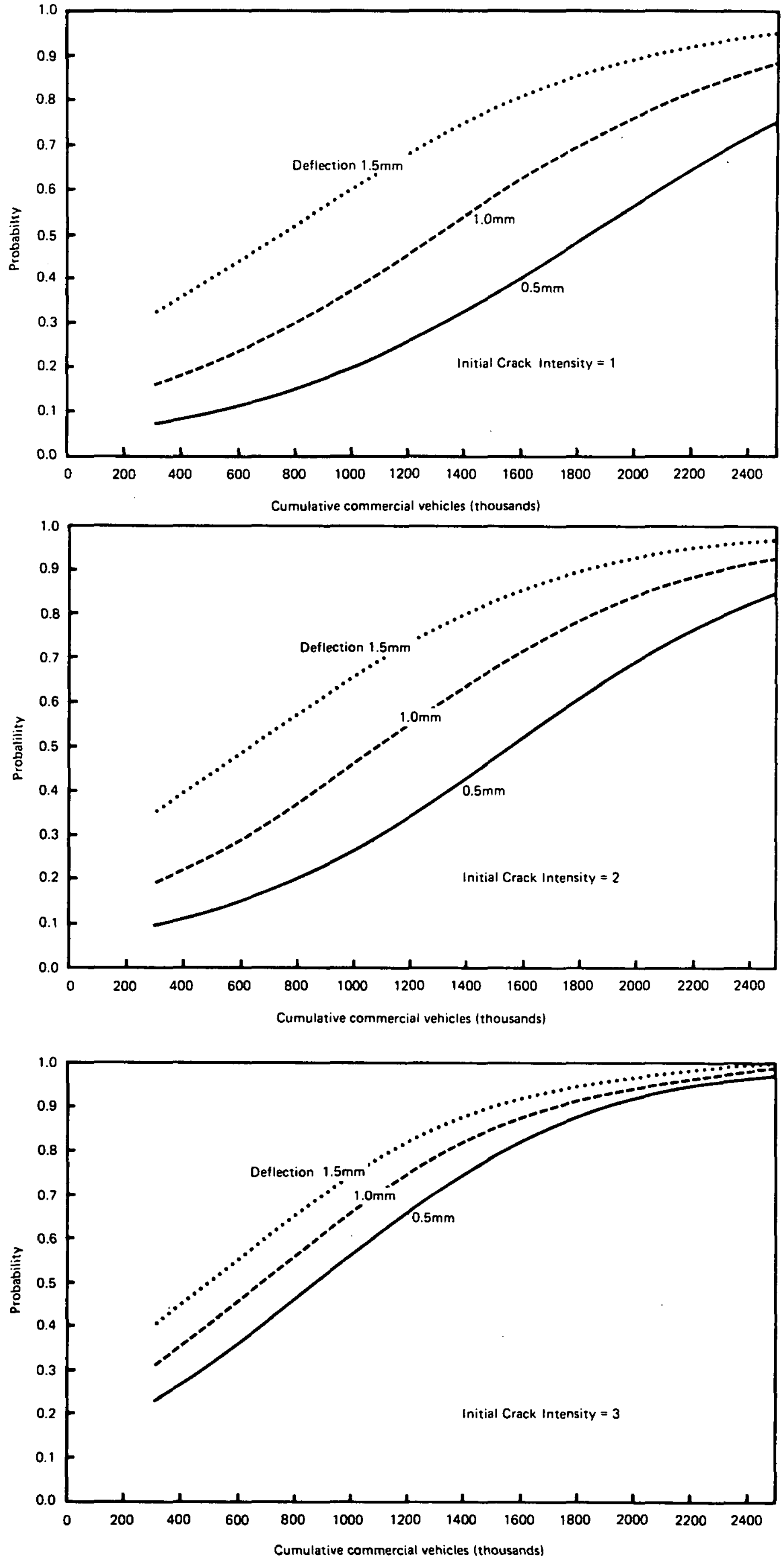


Fig.2 Probability of cracking

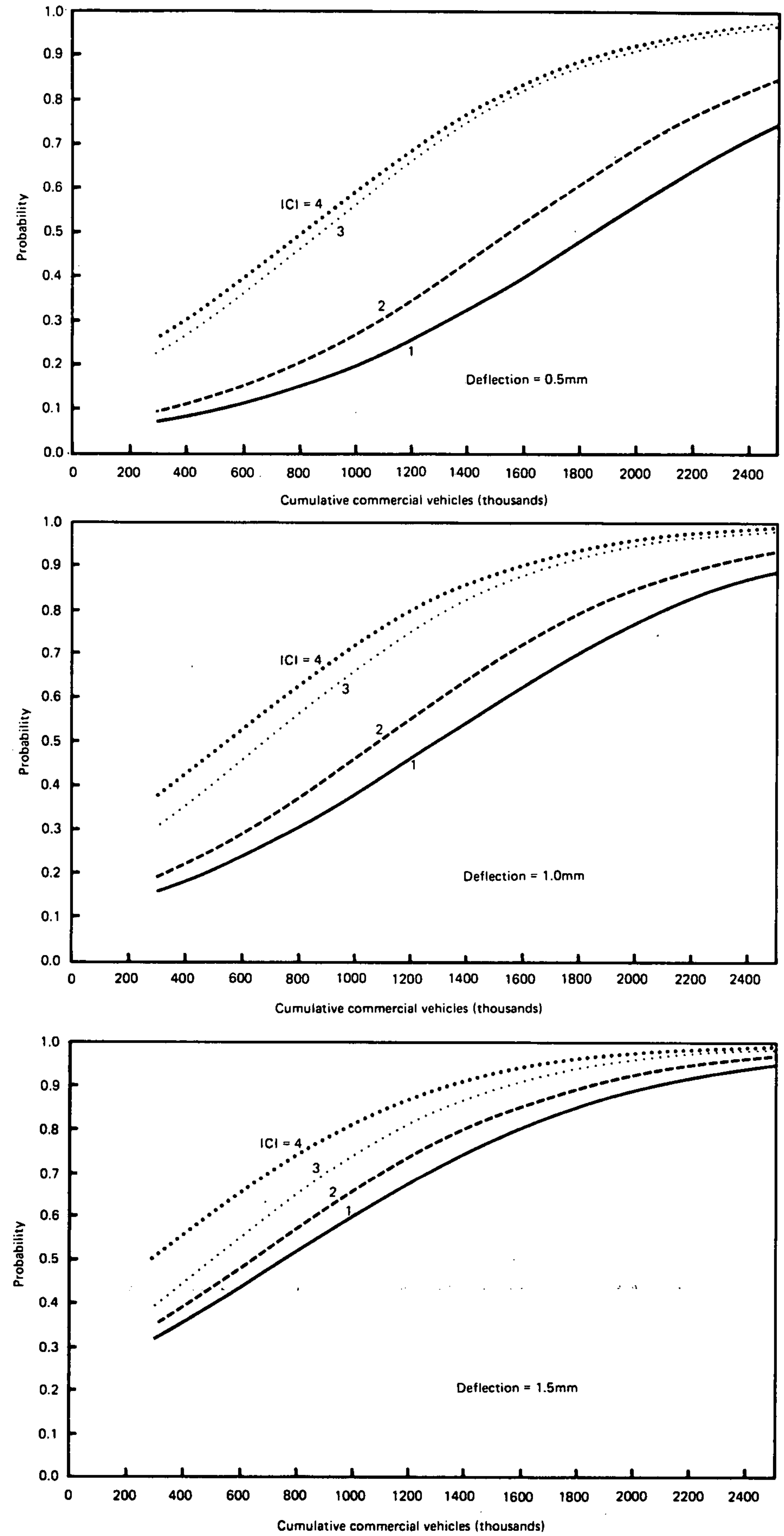


Fig.3 Probability of cracking