Road safety and drain asphalt (ZOAB)

Paper presented at the International conference 'Road safety in Europe and Strategic Highway Research Program', Lille, France, 26-28 September 1994

D-94-25
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Leidschendam, 1994
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In response to a request by the Road and Hydraulic Engineering Division (DWW) of the Ministry of Transport and Public Works, the SWOV has performed a study into the road hazard associated with drain asphalt (ZOAB).
This study consisted of a statistical analysis of accidents on motorway carriageways resulting in injury or material damage. The results showed that porous asphalt is as safe as dense asphalt (DAB). Neither is there any demonstrable difference in risk (probability of an accident) between either road surface type during rainy (wet) conditions or dry weather conditions. The study has not been able to give a complete picture of road hazard on ZOAB surfaces, however, because the data only related to road sections without entry and exit points, bifurcations and slip roads. Further study into this aspect is recommended.

Draining road surfaces made of highly porous hot-rolled asphalt (ZOAB) have been applied on Dutch roads, particularly on motorways, since 1987. ZOAB is an asphalt mixture with a high stone content and a high percentage of hollow spaces, creating interconnected pores. This provides the material with a number of attractive properties:
- The noise resulting from contact between tyre and road surface is considerably reduced in comparison to other asphalt types, and the engine noise is also muffled.
- During rainy conditions, the water can rapidly drain away through the pores of the asphalt and flow off to the side of the road. As a result, the likelihood of aquaplaning is very small and splashing and spraying water is hardly encountered. At the same time, the visibility of road markings remains optimal, since there is no impeding water film.
- The high stone percentage results in the transfer of load via the stone skeleton, so that ZOAB is very resistant to the formation of corrugations in the road surface.

However, there are some disadvantages to be offset against these favourable aspects:

- The open structure of ZOAB can become blocked due to dirt, exerting a negative influence on the advantages offered by the asphalt mixture. The cleaning of ZOAB should therefore be a point of attention.
- ZOAB contributes less to the construction integrity of the road surface in comparison to dense hot-rolled asphalt (DAB).
- When the road surface is dry, the maximum braking deceleration is less than is the case for dense asphalt. This is because the coarser macrotexture reduces the contact area between tyre and road. In addition, the stone skeleton on the upper surface of newly laid draining asphalt is still covered by a bitumen film, thereby reducing the initial friction. After a period of time, this film wears off, depending on the volume of traffic. Measurements have shown that the average deceleration while braking with locked wheels on newly laid ZOAB is approximately 6 m/s^2, on 'old' ZOAB approximately 7 m/s^2 and on DAB approximately 8 m/s^2.

Based on the above properties of draining road surfaces, the following suppositions were made for ZOAB:
- During *dry road surface* conditions, a negative influence on road safety is anticipated as a result of the increased braking distance and the reduced initial friction.
- During *wet road surface* conditions, a positive effect is expected due to improved contact between tyre and road (minimal probability of aquaplaning and skids) and a better view of

the road and other road users.
- With the transition from *drain* asphalt to *dense* asphalt, spraying and splashing water will suddenly be encountered if the road surface is wet. If, during conditions of darkness or lack of attention on the part of the driver, this transition is not observed in time, the driver may be startled. Furthermore, the contact area between tyre and road is then reduced.
- With the *transition* from *dense* asphalt to *drain* asphalt during wet road surface conditions, both contact between tyre and road surface and visibility improve. It is not anticipated that problems will occur under these conditions.

Based on these suppositions, the following study question was formulated:
To what degree and in what manner does the road safety associated with drain asphalt differ from that of dense asphalt, both during dry road surface conditions and during rainy or wet road surface conditions.

Setup of the study
The study consisted of a statistical analysis of accidents registered on the carriageways of motorways with dense asphalt surfaces (DAB) and draining asphalt surfaces (ZOAB). It was decided to only investigate 'pure' road sections first. These are road sections without discontinuities such as entry and exit points and slip roads. On such road sections, there is question of less disruption of the traffic process, making it easier to determine the relationship between asphalt type and road safety. Since the presence and year of construction of ZOAB almost always differs from one carriageway to another along a particular stretch of road, a distinction was made on the basis of driving direction: road sections. A road section commences at the point of traffic entry, a bifurcation or a change in the number of lanes, and has a minimum length of 500 m. As there is difference in the traffic process and in driving behaviour with respect to the number of lanes, the road sections were also distinguished on the basis of this criterion (two lanes or three to four lanes).

The study included both accidents resulting in injury and/or fatalities and accidents causing material damage. Furthermore, a distinction was made on the basis of the condition of the road surface: dry versus wet (including rain) and according to vehicle category: passenger cars and vans (light vehicles) versus lorries and buses (heavy vehicles). Accidents registered on road sections in the year the ZOAB asphalt was laid were not included, in order to exclude the disruptive influence of the associated road work on the statistical results.

Composition of the sample group
The study included almost all road sections on national motorways with two or more lanes, regardless of whether or not accidents had occurred on that road section. In 1991, approximately 15% of the motorway network was covered by ZOAB; the number of ZOAB road sections is therefore much smaller than the number of DAB road sections. In addition, ZOAB is more likely to be found on busier stretches of road, in line with policy to combat noise pollution. As a result, the composition of the group of DAB road sections differs from the group of ZOAB road sections with regard to road and traffic characteristics.

Research methodology
The road sections differ in length, traffic intensity and registration period of accidents. These differences in exposure are corrected by relating the number of accidents per year to

the number of vehicle kilometres covered per year. No correction was possible for differences in the proportion of lorry traffic. Comparison of the road sections was also performed per intensity category. This avoided comparison of busy road sections to less intensively used road sections.

In the first analysis, *all road sections* from which data could be obtained were studied collectively. Due to the differences in composition between the group of DAB and ZOAB road sections as previously described, a second analysis was performed on selected *road section pairs*. For this analysis, each ZOAB road section was paired with a closely matching DAB road section on the basis of road and traffic characteristics, taking particular account of the number of traffic lanes, the length of the road section and the traffic intensity. Although the 'pairs' study offers a more accurate comparison than the study of 'all road sections', the study could only analyse smaller numbers.

Techniques of analysis
With the study into 'all road sections', exploratory multi-variate techniques of analysis were used to define the complex influence of variations in road and traffic characteristics between the DAB group and the ZOAB group, as these variations could distort any differences in road hazard between DAB and ZOAB road sections. The techniques used - HOMALS: homogenity analysis, and CANALS: canonic correlation analisys - are based on mathematical models and are intended to provide an insight into the relationship between the road and traffic characteristics studied and the accident risk.
With the analysis of the paired road sections, a statistical assessment was performed using log-linear Poisson models (WPM): it was examined whether the type of road surface (DAB vs ZOAB) is strongly related to the accident risk.

Description of data material
The study utilised the following data:
- All accidents registered by the police on national roads during 1990 and 1991. These data were derived from the Department for Statistics and Data Management (VOR).
- Data from 1990 and 1991 about road sections, traffic intensities and the proportion of lorry traffic on motorways. These data were obtained from information from the Netherlands Transport Research Centre (AVV) of the Ministry of Transport and Public Works.
- Data from 1991 about the distribution and year of construction of ZOAB on motorways. This information was provided by the Road and Hydraulic Engineering Division (DWW) of the Ministry of Transport and Public Works.

In total, the database for analysis spanned two years and included 2,373 road sections with two or three to four lanes.
The total length of road sections with DAB surfacing is 3,674.4 kilometres; the total length of road sections with ZOAB surfacing is 262.1 kilometres.
6,215 accidents occurred on these road sections: 5,596 accidents on DAB and 619 accidents on ZOAB. Table 1 sets out the principal data used in the analysis for all road sections. The number of accidents registered on the transitional road section was not included in this table, as their number proved to be too small to allow useful statements to be made about differences in road hazard on the basis of road surface transitions. For the same reason, no statements could be made about differences in injury severity for accidents registered on DAB and ZOAB surfaces.

For the 'paired study', the database used for analysis enabled the selection of 83 pairs of DAB-ZOAB road sections, with 433 accidents on 199 kilometres for DAB and 367 accidents on 151 kilometres for ZOAB (= 59.3% of the original number of accidents on ZOAB). Table 2 shows the total length of these paired road sections and the total number of accidents.

Statistical analysis and assessment
The principal results of the statistical analysis and assessment performed are outlined below.

Analysis of all road sections
The HOMALS method was used to study to what degree the variables - characteristics of the road sections, including DAB and ZOAB - are interrelated.
It appears that there is a strong, what could be considered 'normal', relationship between the total number of accidents, the accidents with light vehicles, the accidents with material damage only and - to a somewhat lesser degree - the number of accidents on a dry road surface. The type of road surface (DAB or ZOAB) does not appear to offer any differentiation on the basis of the number of accidents recorded per road section.
The CANALS method was applied to investigate which variables are characteristic for the presence of either a DAB or ZOAB surface. It was shown that the DAB and ZOAB road sections differ from each other with respect to the number of lanes, the motor vehicle intensity and to some extent the proportion of lorry traffic. Again, there is no link between the type of asphalting and the accident risk.

Analysis of paired road sections
WPM was used to assess whether the accident risks on DAB and ZOAB road sections, distinguished on the basis of intensity category, number of lanes and weather condition (wet/dry) differed significantly from one another. It was concluded that there is no difference in risk between DAB and ZOAB. Furthermore, it was shown that a rise in traffic intensity is associated with an increase in road hazard, regardless of whether the road surface is DAB or ZOAB.
With regard to the influence of weather conditions, it was found that there is no difference in risk between DAB and ZOAB during rainy (wet) conditions or with a dry road surface. It should be noted, however, that the accident risk during rainy conditions is over twice that associated with dry conditions for both DAB and ZOAB road surfaces.
An insufficient number of paired road sections (8) was available for pairs representing three or four lanes to allow sufficiently reliable statements to be made.

Further study
Due to the small number of study data, the study result (ZOAB is as safe as DAB) has shown a distribution indicating that the actual difference in risk can vary between minus 10 to 15% (ZOAB safer) and plus 10 to 15% (DAB safer). To allow any difference in risk between DAB and ZOAB road sections to be determined with greater accuracy, it is recommended that this study be repeated and expanded with data covering several additional years.

It is also recommended that a road safety study be performed on those stretches of motorway where entry and exit points and slip roads occur, since the completed study only examined the effects of ZOAB in relatively simple, uninterrupted road traffic situations.
It should also be noted that the greater visibility on ZOAB surfaces during wet or rainy

conditions may lead to higher speeds and shorter following distances than on DAB surfaces during wet or rainy conditions. As a result, the gain in safety which could theoretically be anticipated is nullified. Another possibility is that during rainy and wet conditions, fewer traffic jams occur on ZOAB surfaces as a result of these shorter following distances and higher speeds. It is recommended to perform further study in order to test these suppositions.

Table 1

Database used to analyse DAB and ZOAB road sections with two lanes or more than two lanes

	DAB 2 lanes	DAB > 2 lanes	ZOAB 2 lanes	ZOAB > 2 lanes
Length of road section (in km)	3392.8	281.6	178.2	83.9
Vehicle performance (in km * 10^6)	22970.4	2294	1681.7	1491.9
All accidents on all road sections	4538	1058	380	239
Number of accidents on wet road surface	2876	699	231	171
Number of accidents on dry road surface	1041	273	117	53
Number of accidents during rainy conditions	631	175	69	35
Number of road accident victims on all road sections	318	36	18	11

Table 2

Length and number of accidents for paired road sections

	DAB	ZOAB
Length in kilometres	199.1	150.8
All accidents	433	367
Accidents on dry road surface	288	220
Accidents on wet road surface (including rain)	110	111
Unknown	35	36