Foundation management and maintenance
network of main roads in the Netherlands

Object control regime pavements 2001

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Expertise Centre Management and Maintenance
Ministry of Transport, Public Works and Water Management
Directorate-General for Public Works and Water Management
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Contents

1 Introduction

The present Object control regime pavements (OCRP) Report has been prepared by the Objectives Centre of Expertise as part of the Interim Report Foundation Management and Maintenance of the Objectives Centre of Expertise (Dutch acronym EBO for Expertisecentrum Beheer en Onderhoud) of the Road and Hydraulic Engineering Institute (Dutch acronym: DWW for Dienst Weg- en Waterbouwkunde) of the Directorate-General for Public Works and Water Management (Dutch acronym: RWS for Rijkswaterstaat). The present OCRP Report is an appendix of this interim report; the main report includes only short summaries of the assorted OCRs. The information contained in this OCRP is based on the expertise of various DWW researchers, and on the first results of the SHRP (Strategic Highway Research Programme) study and on the following documents:

- Report foundation maintenance (Study group Kisjes)
- Pavement Study / IVON (Road Management)
- Report Study Group Solid Pavements (Road Management)
- Audit Droog (DHV) (“Droog” infrastructure meaning roads and tunnels)
- Memorandum DWW on the vision of Rijkswaterstaat on the DHV Audit
- Various DWW memorandums on potential control methods and the relationship between (changes in) standards, effects and costs

Please refer to the main report for general information on the characteristics and uses of the main highways, and the specific problems involved in management and maintenance. The present memorandum focuses on pavements. The first version of OCRP 2001 has been developed parallel to and along the lines of the memorandum ‘Controls for Pavements’ (in Dutch: Knoppen voor Verhardingen). This memorandum lists the main consequences for policy-making and budget planning of any changes in standards and guidelines for pavements. The section dealing with the sensitivity analysis and the main conclusions of that memorandum have been included in the present OCRP.

In accordance with the format of the Interim Report, the present OCRP covers the following topics, in that order:

- Characteristics and functions of different types of pavement, including functional preconditions
- Area data and different pavement designs
- Relevant legislation and regulations, legal management pavements
- Civil-engineering functionality and characteristics of pavements, typical wear processes/ deterioration / damage
- Service levels / user demands to pavements
- Maintenance methods of pavements, *key issues* and regular and variable maintenance
- (Intervention) standards, indicative damage, repair standards
- Sensitivity analysis: effects of changes in standards and guidelines
- Topics of special interest: combining activities, special preconditions for execution of works and opportunities for innovation and (efficiency) improvements
- Indication of average costs involved in implementation of this OCRP.

2 Characteristic and functions of different types of pavement

Road surfaces and the underlying foundations are the main objects covered by the category pavements. The pavements of the main highways have been designed to enable mobility on the main highway network with private cars driving at a maximum speed of 120 kilometres per hour. Lower maximum speeds apply to other types of roads.

To perform its traffic function properly, the pavement of a road has to meet the following requirements (1) to be sufficiently smooth, (2) to be sufficiently rough, (3) to provide sufficient grip when driving trough bends (a combination of and transversal slope), (4) to provide sufficient load-bearing capacity to communicate the traffic loads to the subsurface without damage, and (5) to have a sufficient transversal slope to drain rain water.

The combined impacts of traffic loads and the weather result in corrosion of the pavement surface and damage to pavements. Maintenance is necessary to avoid the road's functionality being seriously affected. Section 5 lists the risks of different forms of damage to pavements. Section 8 details the relevant standards and guidelines. Around 43 percent of the annual budget for management and maintenance of the main highway network is generally allocated to pavements. The budget allocation for 2001 totalled over 420 million guilders. The current replacement value of all pavements is estimated at 10 billion guilders, excluding groundwork and land acquisition.

3 Area data and different pavement designs

The total length of the main road network currently managed by the Dutch Government is at the moment 3250 kilometres. Most of these roads are motorways: 2000 kilometres dual-carriageway motorways of two lanes each and approximately 250 kilometres with more than two carriageways and/or more than two lanes per carriageway. Non-motorways include approximately 800 kilometres of single-carriageway roads and approximately 200 kilometres of dual-carriageway roads. Some of the non-motorways serve as substitute connections. In some of these locations, motorways are planned but have not been constructed as yet.

An impression of a Dutch motorway with very porous asphalt

The total area covered by pavements is approximately 86 square kilometres. In the year 2001, 48 percent of this area is covered by non-porous asphalt (in Dutch: dicht asfaltbeton = DAB), 50 percent by porous asphalt (in Dutch: zeer open asfaltbeton = ZOAB) and 2 percent by cement concrete. The ZOAB programme is expected to be finalised around the year 2010, by which time virtually the entire main road network in the Netherlands will be covered by ZOAB. Recent experiments include pavements consisting of so-called double-layer ZOAB and of crushed stone mastic asphalt. The table below lists the most important characteristics of the various types of road surface (see also section 5).

Road surface	**Characteristics**	**Quality in the course of life expectancy**	**Life expectancy**	**Comments**
Non-porous asphalt Dicht asfaltbeton (DAB)	Average	Rutting right-hand lane	Right-hand lane approx. 10 years, other lanes approx. 17 years	
Porous asphalt Zeer open asfaltbeton (ZOAB)	Reduction of noise and splash & spray; better filtering of road water; lower initial ; lower load-bearing capacity in comparison to DAB	Noise-reduction capacity greatly decreases during life expectancy, typical damage is ravelling; no or little rutting	Right-hand lane approx. 8 years, other lanes approx. 15 years	
Cement concrete Cement-beton	More noise generated	Little maintenance	Approx. 30 years	Applicable in regions with poor soil settlement; adaptations to road surface difficult
Double-layer ZOAB Dubbel-laags ZOAB	Very good noise reduction	Not enough experience for general statements	Life expectancy probably shorter than ZOAB	Considerably more expensive than ZOAB, higher production risks
Crushed stone-mastic-asphalt Steenslag-mastiek-asfalt (SMA)		Too little experience to make general statements	Probably approx. 20 years	

At the design stage, the required dimensions of a pavement construction are determined on the basis of both the strength characteristics of the material and the expected traffic load. The traffic load is calculated on the basis of the expected number of times heavy axle loads will pass a certain point. There are five loading classes for asphalt. The heaviest class is mainly used for truck lanes and for the lanes in front of traffic-control units.

rush hour with congestion

Approximately five percent of the total area covered by pavement is located on engineering structures. Since a number of aspects of pavement maintenance on engineering structures differs from regular maintenance schemes, the OCRP Engineering structures focuses separately on this subject

In addition to main roads, the Directorate-General for Public Works and Water Management also manages a number of service roads and bicycle paths, as well as the pavements at its own regional service centres. In view of the relatively limited budget involved, these pavements are not considered in the present OCRP.

4 Relevant legislation and regulations, legal management

The Roads Act prescribes that the road manager is responsible for a proper state of maintenance of the road (liability of maintenance, art. 10). Pursuant to the new Dutch Civil Code, the strict liability for any use of the road rests with its manager. If the manager is held liable for damages to other parties, these damages shall be compensated for, unless it can be shown that the road was in perfect condition. Some standards have been laid down in national or European legislation and regulations. The main standards and intervention levels for the pavements covering the Dutch main roads network are listed in the DWW strategy bulletins 48 and 48a (1996). Legal procedures involving liability generally refer to these standards and guidelines as review criteria. Section 8 provides further details on the origin of these standards and intervention levels. Various other general acts and regulations are important in the implementation of pavement maintenance, e.g. the Working Conditions Act (in Dutch: Arbo-wet) and the Building Materials Decree (in Dutch: Bouwstoffenbesluit).

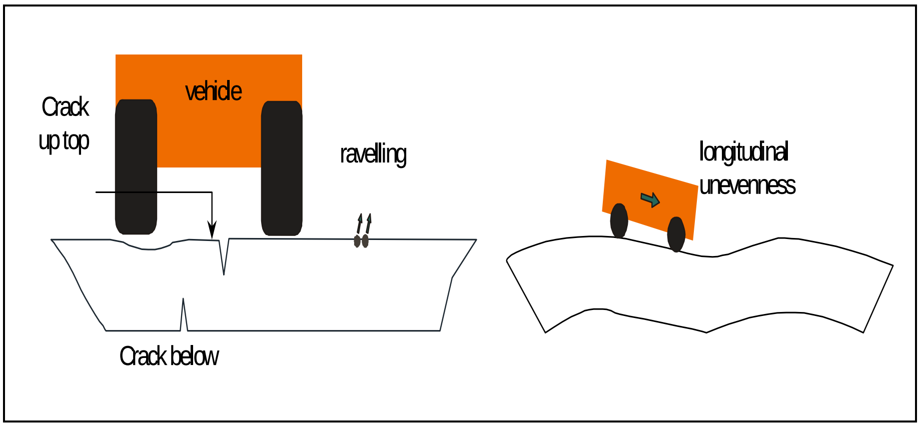
5 Civil-engineering functionalities and characteristics, typical wear processes / erosion / damage

General

The road manager's expertise in pavement maintenance is largely based on experience. Because prior testing of constructions and materials is not easy, experience is usually gained in practical work. Fundamental research is relatively rare: commonly used materials and methods can be studied easily, whereas new ones cannot. Some information can be gained from the so-called SHRP study, in which the behaviour of various pavement constructions is tested under a range of conditions during a limited period. The SHRP report will be issued shortly and DWW has already seen prepublications.

Damage to pavements

One cause of damage to pavements is the weather. As a result of UV radiation and oxygen in the air, bitumen, the binding agent in asphalt becomes brittle and the adhesive capacity decreases. Traffic loading, in particular by heavy cargo traffic[1], is a major cause of damage. The increase in cargo traffic, overloading and particularly (heavy) loads greatly increased pavement damages in the past decade. The increased incidence of slow-moving and stationary traffic caused by congestion is also believed to have a negative effect on the development of damage. Finally, poor soils underlying the roads can also cause damage to pavements[2]. The figure below shows some of the main types of damage that occur in pavements.



[1] Benchmarking has shown that in the Netherlands the maximum vehicle weights allowed are higher than in Germany and Belgium, where the maximum train weights are 50 tonnes and 40 tonnes. The maximum allowed axle loads are, however, identical in the three countries.

[2] The stability of the subsurface especially affects the incidence of deferred settlement. In case of uniform deferred settlement, transversal slope and longitudinal gradient remain largely as they were. The longitudinal gradient sometimes needs to be adjusted only at engineering structures with pole foundations, as these do not take part in the settlement themselves. In case of unequal settlement, adjustments are often needed both in transversal slope (to preserve drainage and the transversal slope of bends) and in longitudinal gradient (to preserve drainage along gutters and to prevent loads from shifting or dropping off). Poor subsurface conditions can lead to a considerable increase in the cost of pavement maintenance. CROW uses a multiplication factor of 1.07 for clayey soils, and a factor 1.29 for mixed clay and peat soils and a factor of 1.52 for peat soils, in comparison with sandy soils. In areas with clayey or peaty soils, road builders should weigh construction time (in particular the time available for settlement), construction costs (choice of earth embankment and its desired settlement characteristics), and the costs of management and maintenance (deferred settlement). Ideally, an LCC approach should be used to select the best combination. Occasionally, however, pressure to start construction rapidly leads to accepting a higher settlement risk. Actually, troublesome deferred settlement only occurs at a number of road sections: parts of the A16 (in the vicinity of Dordrecht), parts of the A6 (Flevopolder) and parts of the A13 (in the vicinity of Delft).

Rutting

Rutting occurs mainly in the right-hand lanes and is caused by heavy loading by cargo traffic in particular[3], in combination with high ambient temperatures. Serious rutting adversely affects road safety and the comfort of road users. Rutting is much more common in DAB than in ZOAB. Because virtually the entire main road network will be covered in ZOAB by the year 2010, the incidence of rutting is expected to decrease considerably.

Cracking

Cracking originating in the upper pavement layer occurs predominantly in DAB pavements and is caused by a lack of cohesion. The traffic load and the impact of the weather cause a reduction in cohesion between (crushed) stone and bitumen. From the point of view of civil-engineering considerations, cracking should be tackled as soon as possible, to prevent freezing up of crack filling, which may cause structural damage to the road foundation. In actual practice, this means that cracking has to be repaired before road users notice serious problems. Cracking in the bottom layer that 'rises' to the upper layer indicates structural damage to the pavement construction, possibly resulting from an insufficient load-bearing capacity of the construction. In these cases major repairs are usually needed.

[3] Overloading lorries is a major cause of (additional) damage to pavements. The resulting damage is estimated to amount to approximately 24 million euros a year.

Ravelling

Ravelling also called erosion of the surface layer, is caused by (crushed) stone coming unstuck from the pavement and wearing away of the mortar. This results in a rough road surface. Ravelling may be due to either traffic loading or the impact of the weather, and is much more common in ZOAB than in DAB. Typical for ravelling is that the damage increases rapidly once the first signs of a rougher surface appear. For road users ravelling causes a reduction in comfort (more noise, uneasy steering) and an increased chance of windscreen breakage caused by the loose pebbles. Severe ravelling also adversely affects road safety.

Longitudinal unevenness

Longitudinal unevenness is a kind of lengthwise wave formation in the road surface. Seam formation is defined as a transition that is less smooth. Seam formation occurs mainly where engineering structures join the road surface and tunnels or a culvert cross under the road. Longitudinal unevenness mainly causes a reduction in comfort for road users. Severe longitudinal unevenness may also adversely affect road safety. The loads of lorries may start shifting as a result of longitudinal unevenness.

transversal slope

The transversal slope of the pavement has a dual function. Firstly, in lanes some degree of transversal slope is necessary to ensure proper drainage of rainwater. If the transversal slope is too small, too much rainwater remains on the road, which adversely affects driver comfort and road safety. This causes more problems for DAB pavements, however, than for ZOAB pavements. Secondly, the transversal slope of the pavement improves vehicle stability in bends. Especially in relatively sharp bends, e.g. at some entries and exits, this is crucial for road safety.

Deterioration of pavement may be caused by the polishing action of traffic. A reduction in may result in cars skidding more readily when braking, which obviously adversely affects road safety. If road users are familiar with a particular road's slipperiness, distances between cars will increase. This will adversely affect accessibility.

Life expectancy

As mentioned before, the load exerted by lorry traffic greatly affects the development of pavement damage. The right-hand lanes, which are commonly used by lorries, therefore, need major overhaul sooner than the other lanes. A right-hand lane made of DAB pavement usually lasts some ten years, whereupon the width of that lane is repaired. The equivalent period for ZOAB is approximately eight years. The life expectancy of an entire carriageway (including lane-specific maintenance) is approximately seventeen years for DAB compared to fourteen or fifteen years for ZOAB. SMA (crushed stone mastic asphalt) has a life expectancy of approximately twenty years while cement concrete lasts approximately thirty years. The next step is replacing the entire pavement.

The life expectancy of a road surface is therefore also determined by its initial quality. The present system requires a road-building contractor to perform additional work in case of faulty pavement quality. In some cases the entire work has to be redone. In case of smaller faults, a deduction is imposed on the contractor's payment and/or partial renovation or an extended guarantee period (from 3 to 5 years) is stipulated. In the current situation, the additional work for the contractor does not make up for the damage suffered by the Directorate General of Public Works and Water Management as a result of the shorter life expectancy; this damage may amount to approximately thirty percent.

6 Service levels / user requirements

During normal use

Maintenance of pavements often directly affects road safety, circulation and driver comfort, and to a lesser extent the quality of life and looks. The main topics of interests are skid resistance of the road surface , the presence of ravelling or cracks in the road surface, longitudinal unevenness and transversal slope. Once pavement damage develops, the service level immediately decreases. In most intervention levels, this decrease in service levels is taken into account (see table in section 8). Section 9 lists the impact on policy-making and budget allocation of diminishing or increasing the intervention levels for the current service levels.

During road works

Road users cannot always make use of a road's entire capacity. Road capacity is especially reduced during road works and when dealing with accidents and other incidents. Since incident management is considered to be part of the topic Traffic Facilities (in Dutch: Verkeersvoorzieningen), it will not be dealt with in the present report.

Three aspects affect the road capacity available during road works – and thus the accessibility: Frequency of maintenance (how often does a stretch of road need to be worked on?), duration of the works (how long will the inconvenience last?) and the remaining capacity available (how many lanes remain?). These three aspects will be briefly detailed below.

The advantage of comprehensive maintenance, where various maintenance works are combined, is that the road user is inconvenienced less frequently. An added advantage is cost saving, as traffic-control measures have to be taken less frequently. However, an 'ideal timing' to carry out road works from the point of view of business economics cannot be realised, resulting in increased costs. Present estimates of comprehensive maintenance are at most ten percent higher than non-combined maintenance.

Concerning the duration of road works, it is generally cheaper to spread works over a longer period, permitting normal daytime work. This is, however, impossible in actual practice in many places, as traffic would come to a standstill. That is why road works increasingly take place in the evenings, nights and weekends. The work has to be completed in as short a time as possible, limiting severe daytime obstruction. Using so-called counter flow (contra flow) systems may limit capacity loss during road works. One of the key problems in this respect is that on narrow roads there is too little room available to direct traffic away from the blocked lane as a 60-centimetre-wide safety strip between the pylons and the working space has to be observed. This often decides which roadwork method is chosen. The Contraflow[4] report (DWW, 2000) describes various possibilities and the matching financial consequences. The main conclusion is that counter flow (4-0), in comparison with other potential alternatives, does not result in a substantial cost increase, whereas, on the other hand, it presents obvious advantages for both the safety of road workers and the flow of traffic.

[4] Nowadays, planning of road works is based on the guidelines listed in the Contraflow report.

Contraflow (4-0), pavement maintenance

The option of completely closing off a carriageway can only be implemented in places where detour routes have sufficient capacity. The advantage of completely closing off a carriageway is a considerable reduction of the costs for traffic-regulations measures and for road-worker safety measures. On the other hand, traffic is generally severely inconvenienced and the detours become severely congested, which may also affect road safety. Moreover, the costs of communication and informing the public about road closures are generally high. Experts, however, estimate that the total costs for complete road closures are lower than for the alternatives where traffic is not diverted. The Directorate for the province of South Holland is studying the financial effects of road closures as part of a corridor approach.

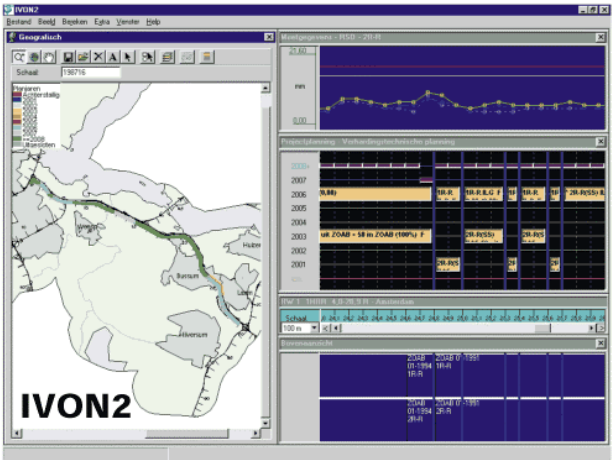
Road works that will considerably hamper traffic flow will increasingly be announced in the media. This will avoid drivers being confronted with delays unexpectedly. It may also reduce traffic volume because some drivers may opt for alternative routes or modes of transport. The annual cost of such communication with road users is estimated at approximately 5 million EURO.

7 Maintenance methods, key issues involved in maintenance, regular and variable maintenance

Regular and variable maintenance

Variable maintenance includes mainly major maintenance projects during which the road surface is replaced or repaired. So-called life-expectancy-increasing maintenance, such as tackling rutting, slippery roads or crazing, is also regarded as variable maintenance. Approximately 75 percent of the budget for pavement maintenance is spent on variable maintenance and the remainder on regular maintenance.

ARAN monitoring in progress



a screen with IVON information

Variable maintenance measures depend on the condition of the road. Damages are recorded by the Automatic Road Analyser (ARAN). This is an intelligent measuring device, which, while cruising along a road, measures its skid resistance, rutting, surface damage and – soon – longitudinal and transversal flatness. The information is recorded and processed by a dedicated Information System for Pavement Maintenance (Dutch acronym: IVON for Informatiesysteem Verhardingsonderhoud). The measurement and observation data are checked and verified by a pavement engineering advisor and eventually result in recommendations regarding timing and extent of the required maintenance measures. These recommendations are, nowadays, more or less binding, ensuring rational pavement maintenance. The eventual maintenance measures are decided on the basis of further inspections and possibly additional research.

Regular maintenance is nowadays decided on the basis of indicators and includes the following items (please refer to “Basic principles management plans (in Dutch: “Uitgangspunten beheerplannen droog”) 2002-2007):

- Small-scale pavement maintenance, called grey maintenance, e.g. cleaning ZOAB, cleaning and maintaining drains (gutters, gulley’s and sewage drains) and roadsides as well as various types of groundwork such as lowering roadsides and removing overgrowing vegetation.
- Weed control of pavement surfaces.
- Doing research or having research done and advising on regular and variable maintenance.
- Repairing damage to pavement caused by collisions and calamities, these damages are mostly recouped from the liable party.

- Taking traffic control measures for the implementation of regular maintenance.

The main aspects of regular maintenance are detailed below. These include forms of regular maintenance of various types of pavements and measures to ensure proper drainage.

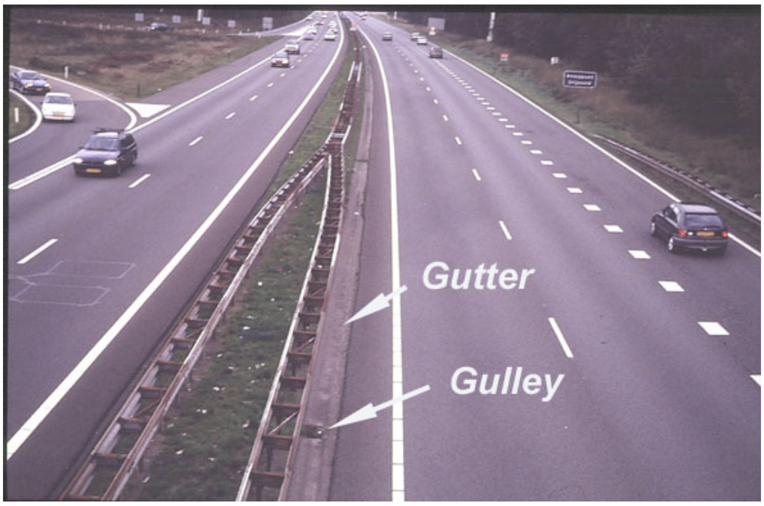
Regular maintenance needed by DAB pavements includes repairing cracks and seams and replacing crazing patches. Early repair prevents more serious damage in frosty weather, when there is a risk of the road surface freezing up and breaking up. In addition, all lanes, hard shoulders and redress lanes are swept four times a year to prevent windscreen breakage, flat tyres and road-verge pollution.

The low-lying hard shoulders of ZOAB pavements are cleaned internally twice a year. ZOAB hard shoulders gradually become blocked by dirt building up, which blocks drainage. The substance that is removed is polluted and is therefore – after settling – transported to processing plants. Twice a year, ZOAB hard shoulders are also cleaned in the normal way.

Regular maintenance of road surfaces consisting of cement concrete includes repairing cracks, stabilising slabs and sweeping the road surface. Maintenance of sett pavements mainly consists of sweeping and repaving.

Drainage is needed to keep the road surface free from water, and prevent frost damage to the pavement. Moreover, it is important to prevent the road verges and earth embankments from become water-logged, resulting in a reduction in the hard shoulder's load-bearing capacity and earth embankment's stability. To ensure proper drainage, the pavement is laid on a transversal slope, so-called superelevation. In most places water is drained via the road verges to ditches along the roads. The drainage capacity of narrow road verges and median reserves, however, is often not sufficient. If pavements drain onto such narrow verges, a sewage system is needed to discharge the water[5]. Sewage systems are also used in water-collection areas, in places where major water concentrations can be expected (these may affect the earth embankment's stability or cause flooding elsewhere) and where engineering structures and the earth embankment meet (to prevent excessive erosion). A sewage system consists of gutters, gulley's, and drainpipes that drain into roadside ditches. In water-collection areas and in places where the water coming from the road surface is severely polluted, this road water is purified in settling and receiving basins before it is drained to the surface water. In some low-lying locations pumping may be needed to drain the water

[5] Approximately 500 kilometres of left-hand lanes drain towards the median strip. These are located in approximately 500 locations, the lengths of which range from 500 to 2000 metres. So, in total, there are approximately thousand lane-slope transitions. These transition sites may cause drainage problems, in particular in case of DAB pavements. Currently, actual drainage problems exist at approximately twenty lane-slope transitions.



Drainage system motorways

The turf that covers the road verges grows upwards by some one to two centimetres a year. Initially, the top of the road verge is constructed some five centimetres below the top of the adjoining pavement surface. After five till fifteen years, the rising verge starts to block water drainage and the verge level has to be lowered. This process occurs both next to ZOAB pavements (effluent water) and next to DAB pavements (run-off water). The lower-lying verges need to be stripped once every eight years on average. The sides of the ZOAB road surface are cleared and a three-metre-wide section of the adjoining verge is lowered. In accordance with the (Dutch) building materials decree, the stripped-off verge material has to be tested for pollution. Stripped-off verge material can usually be recycled.

The table below shows some area data and maintenance frequencies that are used as a basis for calculating the cost of regular maintenance.

	ZOAB	**DAB**	**Cement concrete**	**Comments**
Area covered by road surfaces	41 km^2	39 km^2	2 km^2	
Close cracks (surface -treatment)		2 % per year = 0.8 km^2		
Fill seams		2 % per year = 60 km		
Replacing crazing	0.5 % per year = 0.205 km^2	0.5 % per year = 0.195 km^2		
Area covered by hard shoulders	8.21 km^2 (of which 80 percent low-lying)	7.88 km^2	0.33 km^2	Total length: 5475 km, surface area: 16.43 km^2
Drainage system				1,000 km gutters,[6] 1,500 km sewage drains, 40,000 gulleys, 5,000 manholes, 20 settling basins
Lowering verges				80 % of low-lying verges needs to be stripped once every 8 years = 700 km per year

The total annual cost of regular pavement maintenance amounts to approximately 50 million euros. Approximately thirty percent of this amount is spent on traffic-control measures. Considering the extent of the costs of regular maintenance the possibilities for cost saving by liberalising standards and guidelines are currently explored. The results of the explorations

[6] 500 km drainage median strip, 100 km vulnerable areas, 200 km water concentrations and 200 km seams to engineering structures.

will be included in the new edition of the *Handbook Regular Maintenance* (Handboek Vast Onderhoud).

Maintenance measures

The table below shows the most common maintenance measures taken to repair various types of damage.

Rutting	Filling in ruts (if no cracking is present), 4 out - 4 in (if cracking occurs)
Longitudinal unevenness	Surface milling or reprofiling or milling and reapplying
skid resistance	Solvent for bitumen, roughening by blasting, Surface treatment (not on motorways), renewing top coat
Transversal slope	Milling or reprofiling
Load-bearing capacity	Reprofiling
Cracking	Filling with seam filler (should be removed when recoating with asphalt) or emulsion and crushed stone
Seams	As above
Crazing	4 out – 4 in
Ravelling	DAB: local surface treatment (emulsion and crushed stone) ZOAB: sealing or new top coat
End of life	(Business-economic decision) new wearing course and repair and/or reprofiling of the old one
Dirt	Low-lying hard shoulder ZOAB: cleaning (2x) and sweeping (2x) DAB and higher-lying hard shoulder ZOAB: sweeping (4x)
Blockage of road-water discharge	Improving transversal cross-section and or longitudinal cross-section, cleaning sewage system (manholes, gulley's, sewage drains), lowering high-lying verges

In case of damage it may be necessary to take temporary management measures awaiting maintenance measures. Some of these temporary measures could be: imposing speed limits or placing warning signs. Major safety risks sometimes make it necessary to close off an entire stretch of road.

8 (intervention) standards, indicative damage, repair standards

Indicative damages and intervention levels

In actual practice, damage to pavements is usually not restricted to a single type of damage; usually a combination of different types of damage exists. A stretch of road that shows severe rutting may, for instance, also suffer cracking or longitudinal unevenness. The term indicative damage is used when the damage to a particular stretch of road exceeds the so-called intervention level. This is the level at which, according to current standards and guidelines, maintenance has to take place to repair the damage. If, for instance, the rut depth on a particular stretch of road approaches 18 millimetres, i.e. the intervention level for rutting, action should be taken. At that moment, other types of damage in that stretch of road are considered as well. After all, it may be sensible to tackle several types of damage at the same time, both from an economic point of view (cost saving by combining activities) and from the perspective of the road user (limiting the inconvenience caused by road works).

Intervention levels can result both from service levels that are desired by road users as from civil-engineering considerations related to life cycle costing (LCC). The intervention levels decided largely determine the frequency of maintenance activities and thus the cost of pavement maintenance. The main guidelines for the various pavement damages have been laid down in DWW indicators (wijzer) 48 and 48a (version 1996). Intervention levels have been decided in the past on the basis of research into traffic accidents (rut depth and), on the basis of drivers' behaviour on test strips (longitudinal unevenness) and on the basis of expert judgement. Experience in other countries (PIARC) and elsewhere in the Netherlands (CROW) has also been taken into account. In legal procedures involving the road manager's liability, the court usually refers to the standards and guidelines set by the Directorate-General for Public Works and Water Management as review criteria. Some maintenance standards have been decreed by law. European legislation and regulations may also affect maintenance standards. The table below summarises the origin of the main standards for various types of damages.

Damage	Road kenmerk	Explanation
rut depth	safety, comfort	standard based on accidents and cost considerations, related to transversal slope (article 1988)
transversal slope	safety	standard based on costs and road, related to rut depth
longitudinal unevenness	safety, comfort	IRI is an internationally accepted standard (on the basis of a test strip)
skid resistance	safety	standard based on the connection with accidents, no cost consideration
ravelling	safety, LCC	standard based on expert judgement, consequences for windscreen breakage, motorcyclists
cracking	as above	not relevant for ZOAB; standard based on cost considerations and risks for motorcyclists
load-bearing capacity	LCC	no "hard standard"; complex Care method
splash and spray	safety, comfort	no standard for maintenance
noise	quality of life	no standard for maintenance (yet)

The table below lists how often different types of damage to pavements can be considered indicative. The percentage of the annual pavement maintenance budget has been listed for each type of damage. Ravelling is particularly common in ZOAB, whereas cracking is the most frequent indicative damage in DAB. Because the entire main road network will probably be covered in ZOAB by the year 2010, the right-hand column of the table below is most relevant for the future.

Damage	**DAB**	**ZOAB**
ravelling	25	70
cracking	40	
rut depth	10	5
transversal slope	5	5
longitudinal unevenness	5	5
skid resistance	5	5
load-bearing capacity	10	10
Total	**100 %**	**100 %**

Repair standards

The costs of pavement maintenance are also determined by the requirements for the wearing course to be supplied by the road-building contractor. In view of the cost aspects, different standards may be applied for maintenance and for initial construction. This is particularly true for the transversal slope. If the construction standards were to be upheld, a relatively large amount of asphalt would be needed, and costs would be excessive. Construction standards are, however, applicable to rutting, longitudinal unevenness, ravelling and problems. Liberalising the relevant standards would in these cases not result in major cost savings, with the possible exception of longitudinal unevenness.

Damage	**Repair according to construction standard**	**Repair to a lower level**
Skid resistance	X	
Rut depth	X	
Longitudinal unevenness	X	
Transversal slope		X
Ravelling	X	

9 Sensitivity analysis: effects of intensified / decreased / earlier or postponed maintenance

The maintenance condition of pavements often directly affects road safety, traffic flow and driver comfort, and, to a lesser extent, the quality of life and the appearance of the road. The conditions include road-surface skid resistance, the presence of ravelling or cracks in the road surface, longitudinal unevenness and transversal slope. As soon as pavement damages start to develop, the service level offered decreases. Adapting the existing pavement intervention levels often has both policy-making and financial effects. Relaxing standards usually implies that maintenance will take place later, which may result in cost savings.

The memorandum 'Knoppen voor verhardingen'(switches or steering possibilities for pavement) contains the table shown below summarising the effects of relaxing intervention levels. The table is based on relaxing intervention values by 20 percent. The plus and minus signs in the columns indicate a neutral (0), slight (+ of –) or strong (++ of —) effect on the relevant policy objective.

Damage	**Present standard**	**Standard – 20%**	**Reach-ability**	**Safety**	**Quality of life**	**Com-fort**	**Appea-rance**	**Costs mln. p/y**
Skid resistance	0.38	0.30	–	– –		–		0*
Rut depth	18 mm	22 mm	–	– –		– –		0*
Longitudinal unevenness	3.5	4.5	–	–		–	–	– 2
Transversal slope	1%	0.8%	–	– –		–		– 5
Ravelling	25 %	30 %	–	–	–	–	–	– 30

** Further research is needed to determine the extent of these costs. However, the respective sums are not expected to be very high*

Because cracking is less common in ZOAB, and will therefore become a less frequently occurring type of indicative damage the phenomenon has not been included in the table. As mentioned before, cracking of the wearing course of DAB should be repaired early to prevent serious damage to the construction. There is, therefore, little chance of financial gain by relaxing the standards. Cracking caused by insufficient load-bearing capacity of the construction itself virtually always indicates that a major repair operation is needed.

The table below, also from the memorandum 'Knoppen voor verhardingen', outlines the total financial effects of relaxing the existing standards by 40 percent. The effects listed in the table above would be even more pronounced. The table below also shows the effects on the maintenance budget required if the existing standards were raised by 20 percent. The effects of this option would obviously be exactly the opposite of the effects of relaxing the standard shown in the table.

Standard	**costs in million euros per year**
+ 20 percent	+ 12
- 20 percent	- 16
- 40 percent	- 21

Recently, the possibilities of reducing maintenance cost by relaxing some intervention levels have been studied. Preliminary results of this study indicate that no substantial financial effects can be expected from relaxing these intervention levels. It would be useful to repeat such a study for other intervention levels. The opportunities and restrictions for changing maintenance standards permitted by European legislation and regulations also need to be looked into.

It should be mentioned that the memorandum ‘*Knoppen voor verhardingen’* also focuses on various other issues involved in strategy and planning. These are included in the present OCRP in the sections dealing with service levels (operating procedures and communications at WIU), with maintenance methods (*Handbook regular maintenance*), with intervention standards (repair standards), with topics of special interest (sustainable construction, combining activities, maintaining overloading and developments in European legislation and regulations).

10 Topics of Special interest

Sustainable construction

The basic principle in the context of sustainable construction and the related regulations is that the design of the pavement construction should enable the recycling of asphalt (granulate). According to current opinions, recycling should basically be possible market-comparable (“cost neutral”). This principle might, however, impose limitations on new mixtures that are being developed with a view to increasing the life expectancy (see below).

Combining activities

Variable pavement maintenance should preferably be combined with other types of variable pavement maintenance to limit nuisance to traffic and the cost of traffic-control measures. A precondition, however, is that the profits (as a result of more efficient operations) balance the losses (increased costs resulting from maintenance carried out too early and to late).

Rate of adaptation to new standards and guidelines

Standard and guidelines applicable to pavement construction and maintenance occasionally change. An example is the changed width of the pavement profile in the Guidelines Motorways Design (Dutch acronym: ROA for Richtlijnen Ontwerp Autosnelwegen). To enable counter flow the width of one carriage way of a motorway (2x2) has to be 12,0 till 2,5 meter. To ensure that the existing infrastructure meets the new standards and guidelines, considerable investments are often needed. The current implementation policy is that in such situations any - urgent - changes are implemented together with large-scale maintenance and reconstructions. This keeps the costs down as much as possible.

Possibilities for improvements / innovation

Ravelling is the most common type of damage to ZOAB. A longer life expectancy for ZOAB could reduce both the annual costs during the life of this pavement (provided that the costs of the new mix are not too high) as well as limit the nuisance to traffic. Some time ago, research was carried out into developing different ZOAB mixes with a longer life expectancy. A problem is that improving the properties that affect ravelling might adversely affect other aspects such as initial skid resistance, sound-suppressing properties and recycling possibilities. In addition, predictions of life expectancy are often based on assumptions, because practical research involving test strips and sections takes a long time.

An innovation, which, at the moment, stands a good chance of being applied is the use of improved bitumen, probably in combination with a more suitable type of crushed stone and new maintenance techniques such as repave and remix. The ‘Knoppen voor verhardingen’ memorandum proposes to set up a dedicated, wide-ranging, innovative research programme, which should produce applicable results within three years. Environmental aspects, soundproofing aspects and recycling possibilities would definitely have to be taken into account. The table below summarises – in broad outlines – how the additional costs of the more expensive mixes would compare to the savings resulting from a wider spaced maintenance cycle.

Additional life expectancy	Saving	Additional cost	Total
1 year	27	28	-1
2 years	49	38	+ 11
3 years	67	46	+ 21

Besides improving ZOAB, the use of longer-life types of asphalt concrete, such as crushed stone mastic asphalt warrants looking into.

Other topics that warrant attention

- Improving the initial quality of asphalt in combination with tightening the discount regulations for road-building contractors so that the additional costs suffered by road managers caused by the shorter lifespan of inferior-quality road work is compensated better.
- Matching the lifespan of the constituent parts of a single construction, e.g. the pavements on engineering structures, the left-hand and right-hand lanes and the road markings and road surfaces.
- Taking into account the specific situation when choosing a pavement construction. For instance, there is less need to use ZOAB in locations that are less sensitive to noise pollution.
- Research into the possibilities of combating the reduction of noise-proofing qualities of ZOAB during its life.
- Reinforcing the pavement constructions of the heavily used right-hand lanes even more. Moreover, the design load should in general be future-proof, i.e. match the use realistically to be expected by heavy lorry traffic in particular.
- Reducing the repair standards for road surfaces, especially concerning the longitudinal unevenness; this may reduce the need for applying expensive profile layers later.
- Overloaded lorries cause considerable damage to pavements. The estimated total annual costs of the ‘extra’ maintenance may amount to 23 million Euros. As part of the project Overloading (in Dutch: Overbelading) a monitoring network, commissioned by DGG, is currently being installed comprising WIM-VID systems to detect and bring down the number of overloaded lorries on the main road network. There are agreements on enforcement with the KLPD (National Police Force) and the RVI (Rijksverkeersinspectie = National Traffic Inspection). The additional annual costs of the systems and of the additional enforcement amount to approximately 5 million euros, resulting in an expected annual saving of up to 18 million Euros.

11 Indication of costs involved in implementing OCRP

The summary below shows the costs of pavement maintenance. The cost have been calculated for several years (longest life expectancy) and divided by the number of years. The following premises have been used.

Area

We have distinguished the right-hand lanes, the pavement of which needs more frequent maintenance and the remainder of the pavement. The lengths and surface areas of the various types of road sections (right-hand lanes, other lanes, hard shoulders) have been calculated using winfrabase (road data system). The summary only takes into account the costs of management and maintenance of pavements on earth road embankments; pavements on engineering structures are dealt with in the OCRP engineering structures.

Maintenance frequencies variable maintenance.

- ZOAB right-hand lanes once every 8 years (total replacement once during the total pavement lifespan); indicative damage is ravelling.
- ZOAB entire carriageways once every 15 years; indicative damage is ravelling.
- Dab right-hand lanes once every 10 years 40% (replacing once completely/ for forty percent during the total lifespan of the pavement; indicative damages are rutting and cracking.
- DAB entire carriageways 17 years; indicative damages are rutting, cracking and ravelling.
- Cement concrete only annual regular maintenance; the life expectancy is approximately 30 years and the pavement itself is usually only tackled in case of major reconstruction.

Lifespan

The annual costs have been calculated by dividing the total costs during the pavement’s lifespan, i.e. the regular and variable maintenance costs, including any replacements at the end of the pavement’s life, by the length of this lifespan, expressed in years. The costs per unit have been taken from the RSO database (Rijkswaterstaat Steunpunt Opdrachtgeverschap = support unit for commissioning works) and may be used for business-economic estimates.

Additional costs

Re-profiling DAB-ZOAB	100 percent: existing DAB road surface is routinely re-profiled to ensure evenness and load-bearing capacity
Re-profiling ZOAB-ZOAB	10 percent: only parts of the old ZOAB road surface needs to be re-profiled to ensure evenness
Repair foundation layers when road surface is replaced	5 percent: only bad and weak patches need to be tackled
Implementation costs, general costs, profits and risk	Respectively, 7 percent, 8 percent and 5 percent

The table below lists the additional costs of traffic-control measures required during pavement maintenance. These costs (thousand guilders: 1 euro = 2,2 guilders) have been calculated on the basis of the DWW reports ‘Ondstrat’ and ‘Contraflow’.

Situation with permanent traffic measures and safety barriers

amount per 5 km one carriageway, thousand guilders	day works	night works	4-0 counter flow	3-1 counter flow	detours
civil engineering	1850	2050	1390	1665	1850
traffic-control measures including additional costs	152	363	1140	1920	600
total	2002	2413	2530	3585	2450
% traffic-control measures in	7.6	15.0	45.1	53.6	24.5
% traffic-control measures op	8.2	17.7	82.0	115.3	32.4
of 1850	1,082	1,304	1,368	1,938	1,324
rounded off	10	30	35	95	30

One lane closure with arrow-car

Regular maintenance

The summary takes into account the following measures:

- DAB: filling in cracks and seams, replacing crazing patches, sweeping the road surface.
- ZOAB: cleaning and sweeping the road surface.
- Cement concrete: repairing cracks, stabilising slabs, sweeping the road surface.

- Sett paving: repaving and sweeping
- Drainage system: cleaning gutters, gulley's, sewage drains, lowering road verges.

Please refer to section 7 for more information on the areas and maintenance frequencies used here.

Information to the public

The public is informed in media campaigns about all road works that are expected to cause major traffic obstructions or involve detours. This meets road users' demands to be informed about delays and detours in advance. It also limits the number of complaints, which tend to occupy much of the operational organisation's time. The costs of information campaigns are billed to pavement maintenance. A countrywide public information campaign costs approximately 0.18 million euros, smaller-scale campaigns approximately 45,000 euros. Every year, some 15 large-scale and 40 small-scale public-information campaigns are organised, costing some 4.5 million euros in total. This figure does not include very intensive campaigns such as for the renovation of A10 West motorway near Amsterdam. The costs of this type of campaign may amount to 1.35 million euros per project.

Road markings

The summary includes only the costs of new markings on renovated road surfaces, inclusive of a ten percent surcharge for figurations. The OCRP on traffic facilities provides further information about the costs of 'normal' marking maintenance, the so-called 'white' maintenance schemes. The annual cost of these is currently approximately 8 million euros.

Additional work

With respect to variable maintenance, the summary only includes small-scale additional work such as paving work and finishing road verges. Replacing or modifying crash barriers or drainage is not included.

costs x million guilders				reprof/repaving	traffic measures	l-g-p&r (a)	tax add.val	incl d-s-a (b)	
variable maintenance	frequency	costs/u	costs	addition 1	addition 2	addition 3	addition 4	addition 5	
dab-reprofiling	0,0588	21,81	5,62	6,18	8,04	9,64	11,48	13,40	
dab-zoab	0,0588	12,11	28,04	57,48	74,72	89,67	106,70	124,64	
zoab reprofiling	0,0667	19,85	15,10	16,60	21,59	25,90	30,83	36,01	
zoab-zoab	0,0667	16,28	44,50	50,59	65,77	78,93	93,92	109,71	
subtotal			93,25					283,76	
regular maintenance									
cleaning zoab	2	0,2	3,29		3,61	4,34	5,16	6,03	
sweeping zoab	2	0,1	1,64		1,81	2,17	2,58	3,01	
sweeping dab	4	0,1	3,15		3,47	4,16	4,95	5,79	
cracks,seams etc			20,00		22,00	26,40	31,42	36,70	
repaving etc			2,00		2,20	2,64	3,14	3,67	
lowering verges			5,00		5,50	6,60	7,85	9,17	
drains, gutters, sewage etc			10,00		11,00	13,20	15,71	18,35	
research etc			5,00		5,50	6,60	7,85	9,17	
total			45,08					82,72	
total per year = all variable and regular costs divided by number of years								366,47	
additional work 5%								18,32	
total pavements								**384,80**	
information to the public								**10,00**	
subtotal								**394,80**	
road markings	0,1667	4	15,49			18,59	22,12	**22,12**	
plus 10% additional markings									
total object category								**416,92**	
excl additional costs for other variable additional work (crash barriers, drainage etc)								pm	
costs variable maintenance/m2		283,76	80,36	3,53		a= impl. costs, general costs, profit and risk			
costs regular maintenance/m2		82,72	80,36	1,03		b= design, survey and administration costs			
costs pavements/m2		366,47	80,36	4,56		tax added value = 19%			

remarks: table in guilders, all amounts should be divided by 2.2
decimal comma's should be replaced by decimal points in this table