POTHOLES:
A non-technical guide to their causes and prevention
The CSIR has published a comprehensive technical guide on potholes, their causes, identification and repair.

This short, non-technical guide accompanies the longer publication. It summarises the main causes of typical potholes and ways of limiting their formation. The non-technical guide is aimed at people not directly involved in the technical aspects of infrastructure engineering of roads.

Both publications are available free of charge:
Download the documents in PDF format at www.csir.co.za/POTHOLE_GUIDES
or contact CSIR Built Environment:
Tel 012 841 2871 • Email lsibanyoni@csir.co.za

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We have great pleasure in presenting this non-technical brief on the causes and prevention of potholes. This brief accompanies a detailed guideline on the causes, identification and repair of potholes.

Over the past few years, the development of potholes in South African roads has accelerated considerably, leading to serious concern and wide media coverage. The increase in pothole damage can be attributed primarily to reduced preventative maintenance being applied to many roads, combined with particularly wet periods during rainy seasons and rapidly increasing numbers of heavy vehicles.

The technical guide document describes the causes of typical potholes and uses a decision key system to identify the appropriate repair methods. Various methods are described to ensure that repair work is appropriate for the specific type of pothole and that the pothole will thus not form repeatedly due to failure to address the cause. Mechanisms for quality control of pothole repairs are presented. A standard form for use by inspectors during the field rating of potholes and identification of repair methods is included.

Given the extent of the pothole situation countrywide, we believe the CSIR has an obligation, and is also ideally positioned, to produce such a guideline document. Both documents are available freely for use by the various authorities and interested parties. In this way the CSIR wants to ensure all those responsible for roads have access to the guidelines. We hope that the application of the information presented will result in the formation of fewer potholes and more effective corrective actions.

Hans W Ittmann
Executive Director: CSIR Built Environment
INTRODUCTION

The unprecedented occurrence of potholes (Figure 1) during the 2009/2010 summer rainfall season on particularly the South African provincial and metropolitan sealed roads led to widespread concern among road users and significant reporting by the media.

Numerous claims were made against road authorities for vehicle damage caused by potholes and even for serious vehicle accidents resulting from excessively large potholes.

Potholes have always been a problem on paved roads but never to the extent experienced during the 2009/2010 summer rainfall season. The causes of the large increase in the degree and extent of potholes during this period were many, but can probably be attributed mainly to the following:

- Insufficient routine, periodic or preventative road maintenance leading up to the summer;
- Unusually wet conditions for sustained periods;
- Ineffective, delayed or lack of repair of existing potholes;
- Overloaded or excessive heavy vehicle traffic.

The actual costs of potholes in South Africa in terms of damage to vehicles and accidents caused directly by the presence of potholes and other road-user effects have not been quantified. It probably runs into many millions of rand as confirmed by a recent study by the South African Road Federation. The study indicates that potholes are costing motorists R50 billion in vehicle repairs and injury every year (Source – MNet, Carte Blanche – 21 February 2010).

It should, however, be noted that the problem of potholes is not unique to South Africa, with many developed and developing countries having similar problems.

There is no doubt that water is the primary cause of potholes, but the ingress of water into the road structure to cause the potholes is mostly due to the condition of the road surface.
A lack of periodic and/or preventative maintenance (e.g. crack sealing to prevent ingress of surface water into the underlying layers of the road) leads to the development of weaknesses in the road pavement structure. This results in even more cracks that allow rapid access of water into the structural layers of the road during periods of rainfall.

With constrained road budgets, preventative maintenance is reduced or delayed, which increases the potential for the development of potholes during wet weather significantly. The main technique for reducing pothole formation is thus timeous preventative maintenance to the appropriate standards. For the foreseeable future, however, this is unlikely to be achieved fully and the optimum techniques and timing for repairing potholes should be implemented.

The total asset value of South African roads is estimated at R1 trillion (2010), with the value of the paved road network probably making up about 80% of this, thus about R800 billion. New roads and major repairs of existing roads typically cost about R3.5 million per km for a lightly-trafficked paved rural road, while it could be even hundreds of millions of rand per km for heavy freeway structures.

The annual road budget dedicated to paved roads is thus used to maintain the current road infrastructure as well as to provide new roads, where necessary. It is essential that the enormous value of the asset is not allowed to decrease significantly – the costs of restoration would be extremely high.

Figure 1: A large pothole on a major provincial road likely to cause damage to vehicles or possibly even accidents
CAUSES OF POTHOLES

Although the presence of excessive water is the primary cause of potholes in roads, the formation of potholes differs somewhat depending on the environmental conditions, traffic loading, road pavement structure and materials used.

Potholes can also (less frequently) result from diverse, non-structural causes such as diesel (or other chemical) spillages; mechanical damage to road surfaces from vehicle rims and/or accidents and fires; damage caused by falling rocks in cuttings; animal hooves on the road surface in hot weather; and poor road design.

The majority of potholes are caused by the interaction of the environmental conditions, water in the road pavement structure and tyre loads. Water alone in the road will seldom cause potholes, while traffic using a dry, well-maintained road will also seldom generate potholes by itself. Only a combination of traffic and wet or poorly-maintained roads will produce potholes.

When a bituminous (‘blacktop’) road is constructed, the surface consists primarily of a combination of bitumen and crushed stone. Bitumen is a unique material that bonds crushed stone and other aggregate particles together or to the surface of the underlying road layer. The properties of bitumen change with hot and cold temperatures. This allows it to be flexible enough to absorb the small strains (movements) that occur at the surface of the road when traffic passes over the road without cracking during typical road operating temperatures.

Over time, the bitumen ‘dries out’ and becomes harder and less flexible. This is known as ageing, which is a result of, for instance, long-term exposure of bitumen to ultraviolet radiation (from the sun). As this happens, the cumulative movements of the road surface due to the changes in road surface temperature and traffic passes result in a fatiguing of the bitumen, which eventually cracks. This can be likened to the repeated bending of a piece of wire until it breaks.

Only by applying a new bitumen seal or rejuvenating the existing bitumen can the fatigue be avoided. A new bitumen seal obviously returns the road surface to a high degree of flexibility (with some improvement in riding quality), but costs a lot (between R15 and R38 per m²) and may last from seven to about 12 years. The use of rejuvenators (about R5 per m²) provides temporary relief by softening dry bitumen and making it more flexible for a limited period (two or three years).

All roads under traffic and environmental conditions will eventually crack. The time period could be short (in the case of stabilised road layers, i.e. those treated with cement to enable the use of lower-quality local materials, which form cracks naturally as the cement reacts – see Figure 2), or much later. All roads deform slightly every time a heavy vehicle passes over them. Should the surfacing have dried out with time (as is currently the case with the majority of South Africa’s roads), this repeated deformation results in cracking of the bituminous surfacing.
Potholes. It has been noted on certain roads that, as their condition deteriorates, the traffic uses alternative routes instead. When potholes are not repaired timeously, they deteriorate rapidly and become larger and deeper until patching maintenance is no longer possible. Expensive reconstruction of the road is then necessary.

The increasing numbers of heavy vehicles on the rural road network are also accelerating the rate of deterioration of these roads. Roads that are old or designed to carry relatively light traffic (therefore less costly to build) are carrying significantly more heavy vehicles than they should. This results in greater deformations, more rapid cracking and deterioration and ultimately the formation of potholes. It has been noted on certain roads that, as their condition deteriorates, the traffic uses alternative routes instead.

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Figure 2: Typical cracking resulting from stabilised road layers – some sealed, some unsealed
PREVENTION OF POTHOLES

It is unlikely that the formation of all potholes will ever be totally prevented. However, by the judicious use of preventative and proactive maintenance, the incidence of potholes can be reduced significantly.

The first objective should be to ensure that those roads in need of a bituminous reseal are sealed as soon as possible. Prolonging the resealing will result in drying of the surface, loss of surfacing stone, the ingress of water into water-sensitive layers and disintegration of the road under traffic (even in dry weather). This could lead to total loss of sections of the road (Figure 3).

Sealing of cracks is of the utmost importance. The presence of open cracks allows the ingress of water into the pavement layers, decreasing their strength (load-bearing capacity) and making them more susceptible to failure under loading.

A survey of severely deteriorated primary roads has shown that traffic has moved to the road shoulders (Figure 4); in some cases, the majority of heavy traffic has moved to alternative routes, which may not have been designed to carry such loads. This will result in premature failure of these routes as well.

The quality of patching is often poor and many patches do not address the fundamental cause.

Figure 3: Rapid failure of a road surface as a result of neglect to repair potholes
of the pothole, which results in the need to return to patches repeatedly for repair once again. It is essential that more attention is paid to patching and the teams used for this should be better trained and more dedicated.

It can thus not be overemphasised how important it is to maintain the existing road network to as high a standard as possible.

It is recommended that:

- Preventative (and not reactive) maintenance practices should be phased in as soon as possible.
- A well-controlled programme of pavement maintenance should be initiated and appropriate funding allocated specifically for this purpose.
- Roads where the bitumen is dry should be treated with rejuvenators or diluted bitumen emulsion sprays timeously.
- All potholes should be repaired as soon as possible after their formation. Dedicated, well-trained and mobile teams would be required for this.

Figure 4: Extensive damage to shoulders and the road edge as traffic moves on shoulders instead of the potholed and deteriorated road
Maintenance teams are often unskilled or badly trained, leading to ineffective repairs.

The pothole patches are seldom of sufficient quality or depth to address the basic cause of the problem. This usually results in the need to return to the site repeatedly for ongoing repairs.

It is thus essential that more preventative maintenance is implemented and funding for this is provided by the relevant authorities. The heavy vehicles on many of the rural roads should also be controlled in terms of both their numbers and their masses. Pothole maintenance teams must be properly trained and equipped.

CONCLUSIONS

Budget constraints and the allocation of road funding to other priorities reduce preventative road maintenance, with the prevalence of potholes likely to increase significantly. This would, in turn, result in an increase in the number of claims relating to vehicle damage and accidents.

Potholes are typically ‘repaired’ on an ad hoc or reactive basis, often quite some time after their formation, which results in additional deterioration.
Please note: Information on the different categories of potholes, appropriate repair methods and quality control appears in the technical guide on potholes published by the CSIR. A standard form for field assessment and categorisation of potholes is supplied, as well as a key to the identification of pothole repair measures. (Download both documents in PDF format at www.csir.co.za/pothole_guides)
See www.csir.co.za/pothole_guides to download non-technical and technical guides