

Review on the Pavement-repairing Measures as a Condition for the Choice of Road-Maintenance Strategy

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Abstract. The road-maintenance strategies vary from one country to another, and even between the road management authorities within a one single country. It is not surprising, as there is not best maintenance method, nor a universal set of strategies that can be applied equally everywhere. Generally, there are strategies acceptable in certain conditions, but the factors influencing the selection process are diverse and very complex. This paper will present a review of the various measures that can be applied on the roads, which is certainly the basic condition of selection of an appropriate maintenance strategy.

1 Introduction

The selection of the method of maintenance of the road network in a region or on the whole territory of the country is very complex and intricate. Part of the strategy selection procedure includes the knowledge of the available measures and technologies of pavement maintenance. But, the approach must be a multi-disciplinary one as the selection of the road maintenance strategy is not reduced to the choice of the best maintenance measure, but is the selection of an optimal set of activities in a given time period with the purpose of obtaining an acceptable level of service rendered to the users, but with the lowest possible investments by the state.

Some of the factors influencing the application of a certain type of treatments, and thereby the selection of the maintenance strategy include the following:

- Previous maintenance;
- Available materials;
- Access to funds;
- Traffic load;
- Classification of the roads and the method of their use;
- Environmental influence.

Maybe the most important factor is the final effect that a certain treatment will yield onto the pavement in the sense of the pavement behavior and of course, of the users on the

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short and the long run. The review of the maintenance effects starts with an analysis of the generally accepted measures of pavement repair. They are divided into six categories as follows:

- Routine maintenance;
- Preventive maintenance;
- Thin layers;
- Overlay;
- Rehabilitations;
- Reconstructions.

Each category is organized according to the effect that it is supposed to leave on the pavement and its users, on a design period for which it has been envisaged. The pavement repair measures and a short description of the procedures are given in Table 1. The table offers an overall demonstration of the categories and the maintenance types referring to each category. They are presented hierarchically pursuant to their effect on the overall behavior of the pavement. Of course, there are other maintenance methods, but these procedures are the most frequent and the most widely accepted ones in the world.

Table 1. Overall presentation of the maintenance categories and treatment types.

Category	Treatment type	Application method
Routine maintenance	Drainage system	Cleaning of canals, culverts, repair of inlet and outlet heads.
	Crack seal	Bitumen emulsion for temporary repair. Polymer- or gum-modified asphalt materials for long-term protection.
	Edge-break repair	Closed-structure asphalt, cold-procedure mix, emulsion
	Shoulder repair	
	Patching	
Preventive maintenance	Fog Seal	Water-saturated emulsion in the quantity of 0.45 to 0.75 l/m ²
	Rejuvenating Seal	Sprinkling of bitumen or modified bitumen with low viscosity without an aggregate in the quantity of 0.3 to 0.9 l/m ²
	Slurry Seal	Mixture of an aggregate (grain dimension of 3 to 10 mm, filler) bitumen emulsion and water. битуменска емулзија и вода, by adding polymer. This procedure is called micro-overlay)
Thin layers	One-layer surface treatment	Sprinkled bitumen and application of uniform gradation aggregate
	Two-layer surface treatment	Two layers, with a finer aggregate applied on the second one
	Cape Seal	One-layer surface treatment after the application of Slurry Seal
	This asphalt overlays	Closed bitumen mixture 25 to 40mm thick
Overbuilding	Thick asphalt overbuilding	Closed or open bitumen mixtures >40 mm thick
	Modified asphalt	Polymer-modified closed bitumen mixtures
	Modified asphalt	Polymer-modified closed bitumen mixtures
Rehabilitation	Scraping and asphaltting in thick layers	Removal of a part of the layer or of one or two layers and their replacement by new ones.
Reconstruction	Reconstruction	Removal of the entire asphalt to the lower bearing base and its replacement with new layers.

2 Routine maintenance

Routine maintenance can be defined as the treatment of the pavement or of the drainage system when it is necessary, to provide for normal functioning of the pavement and of the road in general. Thus, routine maintenance is often referred to as reactive maintenance, meaning that it is performed as a reaction to specific conditions and damages.

Routine maintenance should be continuous, at least when it includes the drainage and the damages signs on the road. An example thereof is the patching, as it cannot be envisaged as a treatment, but is carried out as the pothole appears.

This also includes winter maintenance of the roads, depending on the climate in the country and/or in the region; it must be taken into consideration in order to timely provide the resources for its performance.

3 Preventive maintenance

Contrary to routine maintenance, in preventive maintenance the treatments are applied before the damages occur. These treatments are meant to prolong the life of the pavement, by restoring or maintaining the desirable characteristics with still economical measures. Maybe the most frequent type of preventive maintenance is the micro-overlay which is applied to protect the pavements against aging and oxidizing. These treatments include application of a thin bitumen layer which is to be absorbed in the surface layer of the pavement.

The preventive maintenance measures are most suitable on pavements which have not yet shown any damage, as is the considerable cracks or disintegration. Most frequently, no aggregate is applied or, if it is, the maximal dimension of the grains is of 10mm. Preventive maintenance is not an efficient method with structure damages, as rutting or crocodile-skin cracks.

1. This layers. They can be applied as preventive treatment, but also to restore the skid resistance and the bearing capacity of the pavement. They are also referred to as functional overlay as they are supposed to restore and increase the capacity of the road functioning, but they not increase the bearing features of the construction. The thin layers are usually applied in case of small cracks, small potholes and minimal rutting. Larger rutting can be treated by filling or in combination with thin surface treatment.

2. Overlay. Overlays primary purpose is to increase the bearing features of the construction. Considerable improvement of the bearing capacity is achieved when the overlay is more than 40mm thick. It is applied in initiation of structural deformations of the pavement (rutting, potholes, crocodile-skin cracks) or in case of increased traffic load which has not been envisaged by the pavement design. It is carried out with an asphalt layer which is also used in constructing of new roads. The best results are achieved by first repairing the existing road and then applying the new asphalt layer.

3. Rehabilitation. Rehabilitation is a large modification of the pavement construction. Unlike the overlay, rehabilitation always includes interventions on one or more asphalt layers. They include scraping, which removes the surface layer and often goes deeper than one layer, with new or recycled material. Rehabilitation is the most effective measure on pavements where signs of structural damage have occurred (most frequently crocodile-skin cracks or rutting), but not to the degree that would require complete reconstruction.

4. Reconstruction. Reconstruction implies removal and replacement of asphalt layers to the sub-base and/or replacement of the blanket course to the grade. Upon partial reconstructions some parts of the original construction are left unchanged. Complete reconstruction consists of removal of all included materials, grade treatment and building of

a new construction. Reconstruction is justified when the pavement is destroyed, and the grade requires enforcement (including drainage).

5. Other treatments. There is other maintenance treatment, but it is not easy to classify them. For example, simple scraping without the application of an asphalt layer or emulsion is also performed to decrease the rutting level or increase friction. If it can be proved that there will be no more rutting, than such a measure is justifiable. If rutting is expected again, this measure is considered as temporary. Recycling is often related to rehabilitation. In fact, it can be part of any maintenance strategy, as many bitumen types and aggregates can be re-used if treated properly. Recycling is an efficient strategy if the materials are in good shape and if the procedure is economical.

4 Maintenance effects

The application of a certain maintenance treatment should be considered immediately after the decision to intervene, before the occurrence of new deformations under the influence of the new traffic load and under the influence of the climate factors. In certain cases all the damages will thus be eliminated, or some of them will be eliminated partially, depending on the treatment applied. The following Tables (2 to 7) give the relation of individual maintenance treatments and their effects on different types of deformations.

Table 2. Influence of certain treatments on the pavement's crack level.

Treatment	Immediate effect after application
Crack seal	Elimination of line cracks
Repair of edge breaks	No effect
Patching	No effect
Fog Seal	Elimination of cracks less than 1mm wide. No effect on wider structural, thermal or reflected cracks.
Rejuvenating Seal	No effect
Slurry Seal	Eliminates the micro-cracks
One-layer surface treatment	Eliminates micro-cracks
Two-layer surface treatment	Eliminates micro-cracks
Cape Seal	Eliminates micro-cracks
Thin asphalt layer	Elimination of surface cracks. The cracks in the deeper layers remain.
Thick asphalt overlay	Elimination of surface cracks. The cracks in the deeper layers remain.
Overlay with modified asphalt	Elimination of surface cracks. The cracks in the deeper layers remain.
Overlay with gum-modified asphalt	Elimination of surface cracks. The cracks in the deeper layers remain.
Scraping and overlay	Elimination of surface cracks. The cracks in the deeper layers remain.

Table 3. Influence of certain maintenance treatments on raveling.

Treatment	Effect immediately after application
Crack seal	No effect
Repair of edge breaks	No effect
Patching	No effect
Fog Seal	No effect
Rejuvenating Seal	No effect
Slurry Seal	Raveling elimination
One-layer surface treatment	Raveling elimination

Two-layer surface treatment	Raveling elimination
Cape Seal	Raveling elimination
Thin asphalt layer	Raveling elimination
Thick asphalt overlay	Raveling elimination
Overlay with modified asphalt	Raveling elimination
Overlay with gum-modified asphalt	Raveling elimination
Scraping and overlay	Raveling elimination

Table 4. Influence of certain treatments upon rutting treatment.

Treatment	Effect immediately after application
Crack seal	No effect
Repair of edge breaks	No effect
Patching	No effect
Fog Seal	No effect
Rejuvenating Seal	No effect
Slurry Seal	No effect
One-layer surface treatment	No effect
Two-layer surface treatment	No effect
Cape Seal	No effect
Thin asphalt layer	Minimal effect. Elimination if a leveling layer is used.
Thick asphalt overlay	Minimal effect. Elimination if a leveling layer is used.
Overlay with modified asphalt	Minimal effect. Elimination if a leveling layer is used.
Overlay with gum-modified asphalt	Minimal effect. Elimination if a leveling layer is used.
Scraping and overlay	Rutting elimination

Table 5. Influence of certain treatments upon the maintenance of potholes.

Treatment	Effect immediately after application
Crack seal	No effect
Repair of edge breaks	No effect
Patching	Elimination of potholes
Fog Seal	No effect
Rejuvenating Seal	No effect
Slurry Seal	Elimination. Potholes must be patched first.
One-layer surface treatment	Elimination. Potholes must be patched first.
Two-layer surface treatment	Elimination. Potholes must be patched first.
Cape Seal	Elimination. Potholes must be patched first.
Thin asphalt layer	Elimination. Potholes must be patched first.
Thick asphalt overlay	Elimination. Potholes must be patched first.
Overlay with modified asphalt	Elimination. Potholes must be patched first.
Overlay with gum-modified asphalt	Elimination. Potholes must be patched first.
Scraping and overlay	Elimination of potholes

Table 6. Influence of certain treatments in maintenance of edge break.

Treatment	Effect immediately after application
Crack seal	No effect
Repair of edge breaks	Elimination of edge breaks
Patching	No effect
Fog Seal	No effect
Rejuvenating Seal	No effect
Slurry Seal	No effect

One-layer surface treatment	No effect
Two-layer surface treatment	No effect
Cape Seal	No effect
Thin asphalt layer	No effect
Thick asphalt overlay	Elimination of edge breaks
Overlay with modified asphalt	Elimination of edge breaks
Overlay with gum-modified asphalt	Elimination of edge breaks
Scraping and overlay	Elimination of edge breaks

Table 7. Influence of certain treatments upon the maintenance of micro and macrotexture (friction).

Treatment	Effect immediately after application
Crack seal	Small decrease depending on the crack location
Repair of edge breaks	No effect
Patching	No effect
Fog Seal	Small decrease of skidding resistance due to the change of macro-texture.
Rejuvenating Seal	Small decrease of skidding resistance due to the change of macro-texture.
Slurry Seal	Increase of the skidding resistance only if applied on a surface of small-grais asphalt. Decrease of the skidding resistance if applied on a surface of large-grain asphalt.
One-layer surface treatment	The new skidding resistance value depends only on the mixture.
Two-layer surface treatment	The new skidding resistance value depends only on the mixture.
Cape Seal	The new skidding resistance value depends only on the mixture.
Thin asphalt layer	The new skidding resistance value depends only on the mixture.
Thick asphalt overlay	The new skidding resistance value depends only on the mixture.
Overlay with modified asphalt	The new skidding resistance value depends only on the mixture.
Overlay with gum-modified asphalt	The new skidding resistance value depends only on the mixture.
Scratching and overlay	The new skidding resistance value depends only on the mixture.

1. Effects of maintenance on roughness. There is unevenness in all pavements regardless of age. The value of IRI is higher than 1 m/km even in the highest-quality asphalts. In many countries, the average IRI value is between 1 and 2 m/km, even up to 2.5 m/km. As the IRI value largely depends on the other deterioration types, most of the treatments decrease its value but it can never be eliminated.

2. Maintenance effects on the structural bearing capacity of the pavement. The pavement bearing capacity gradually decreases with time and under the influence of traffic load and climate factors. These changes must be taken into consideration, as they influence the structural number of the pavement. The structural number can also be changed for a certain value upon application of a treatment, depending, of course, on the treatment itself.

The changes of the values of the structural number depend on the type of repair and the quality of selected materials. The increase of the modified structural number is calculated by multiplying the material change coefficient and its thickness, considering the maintenance treatment.

Table 5 gives the percentages of decrease of change coefficient depending on the intensity of damage for the different layers of the pavement construction.

Table 8. Suggested values of reduction of the change coefficients a_i depending on the pavement condition.

Material	Condition	% of a_i
AB layer	Few or no cracks	75-90
	3-5% of the surface	55-75
	5-15% of the surface	45-67
	>15% of the surface	15-45
Base	Few or no cracks	55-100
	3-5% of the surface	40-70
	5-15% of the surface	40-55
	>15% of the surface	20-55
Sub-base	No proof of swelling and degradation	70-100
	Proofs of swelling and degradation	0-70

The change of the structural number of the construction with time is the basic condition in the selection of the technology that shall be applied upon the pavement repair.

5 Conclusion

The introduction of a road network management system is a precondition for the adoption of a road maintenance strategy. Only with detailed knowledge of the road network, its damages, the needs of maintenance and the available technologies, it is possible to initiate the adoption of a strategy of maintenance, of course, considering the available financial resources. Here, special emphasis should be laid on the analyses of different maintenance scenarios, whereby it is necessary to analyze the funds necessary for each of them, and then adopt the most favorable one considering the available finances, and to establish the future maintenance strategy. The application of this kind of method in planning and programming of the maintenance will contribute to the definition of a strategy of maintenance, by which would provide for the most optimal use of the financial resources in order to provide for the maximal improvement of the economic life of the pavements of the country's road network.

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