MAXIMIZING LIFE CYCLE COST PERFORMANCE WITH NEW GENERATION MASTIC ASPHALT PAVEMENTS

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ABSTRACT

Mastic asphalt is standing the test on heavy duty streets since decenniums, but in particular for tunnels and bridges. The waterproof construction of mastic asphalt pavement is steady, resistant, long-lasting and offers high driving security. Possible structuring of mastic asphalt surfaces with bright and/or special chippings may reduce noise of up to 3 dB.

The high stable mastic asphalt pavements are distinguished through their long useful life. The Life Cycle Cost Performance reached thereby is impressive and in comparison with other pavements, specifically for bridges, a clear favourite.

The method of construction for mastic asphalt was influenced through research and development during the last 20 years essentially. High stable mastic asphalt recipes, special arrangements in processing and transport, but also the new laying concepts are attesting remarkable improvement to the mastic asphalt pavements of the new generation. The high standards of the European Norms are covered entirely and assure extraordinary quality and cost performance to the operators of heavy duty streets.

Mastic asphalt of the new generation for highest demands

Keywords: Design Mix, Life cycle assessment, Mastic Asphalt, Modified Binders, Surface Texture

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Throughout the world, high speed highways are subjected to enormous loads. If maintenance work is required, fewer traffic lanes are available and overload situations are created together with consequent traffic congestion and jams. The huge costs to the economy could however be avoided through correct planning. Above all, high quality of pavement construction is required, not only from the point of view of saving costs, but also to ensure improved availability of road traffic infrastructure. In this respect the life cycle costs are to be taken into account for key traffic carriers. Experience has shown that in the long term, pavement constructions using improved binders and additives, achieve extremely good performances.

1. BRIDGES ARE CONNECTIONS WHICH DEMAND THE BEST QUALITY OF CONSTRUCTION

Without high-speed highways, bridges and tunnels, our environment and economic development would be restricted. Such crucial traffic carriers must be able to ensure the free flow of traffic for as long as possible. Of course civil engineered objects (bridges and tunnels) require more maintenance than roads in open terrain. Civil engineered objects must be protected by waterproofing. Bridge and tunnel pavement constructions must be able to meet significantly higher demands.

Our predecessors have recognized for several generations that good quality is absolutely necessary for bridges.

Image 1
Storebaelt Bridge, Denmark

Throughout the world we can find bridges which have distinguished themselves through long-term usage. In this day and age, the specialist knowledge needed for building such bridges exists. Unfortunately the expertise developed by our predecessors in respect of quality and good engineering, is all too often disregarded. The consequences of this are:

- Repeated maintenance works at short intervals
- Bridge pavements requiring replacement after only a few years
- Unsuitable waterproofing and pavement constructions leading to fast deterioration of the supporting structure (corrosion damage)

The costs of repair works are formidable. An even more significant cost factor is the economic fall out from the non-availability of key objects. The expenditure for repair works to bridges are as a rule approx. 30% - 60% of the original construction costs. At the end of the day, the choice of system and quality of execution (asphalt engineering – construction work) are decisive factors determining the actual progression of this investment of 30% to 60% of the original construction costs. The time cycle is dependent upon quality of execution; it lies between 5 and 35 years. Based on experience, the economic costs incurred as a result of the limited availability of a key object are 40% to 70% of the costs incurred for the repair works [1].

Example of a bridge construction in England

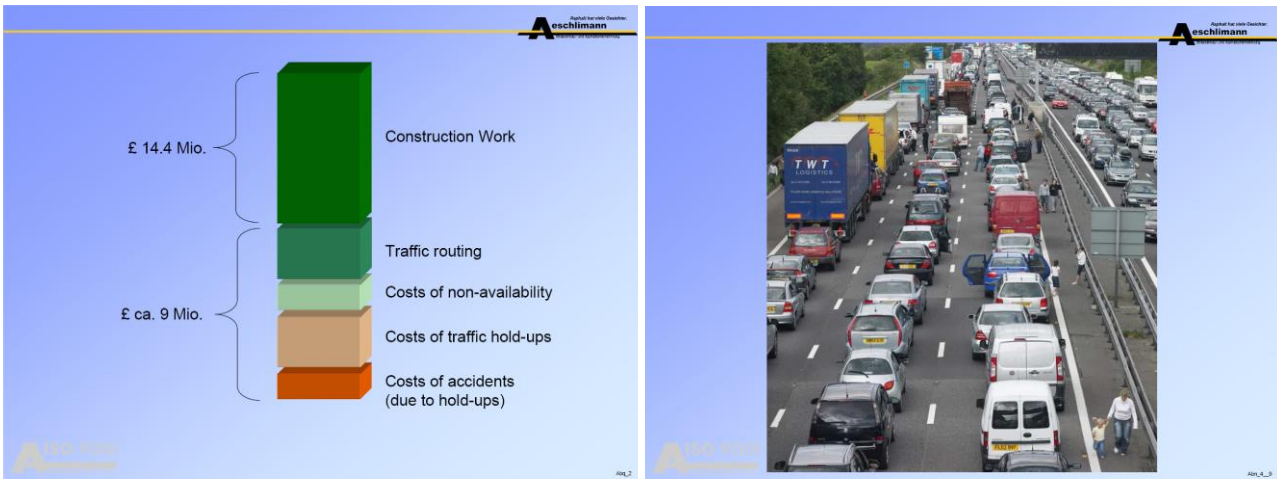

Image 2
Avonmouth Bridge, England

Through better construction methods and superior quality, reduced life cycle costs are able to be achieved.

This does mean that with technical know-how and consistent application of the necessary construction methods, somewhat higher costs must be expected for the initial construction, but that in the long term, significant cost savings can be achieved. In order to attain this objective for key structures (bridges, tunnels), the optimum quality and service performance should be evaluated by special project engineering criteria (asphalt engineering). For this purpose the basic question of the specified parameters is central:

- For which length of time is the structure (bridge / tunnel) to remain operational?
    - International guidelines stipulate that with normal maintenance frequencies, a civil-engineered structure should achieve an operating life of 100 - 120 years. This target can however only be achieved if the structure is appropriately protected. High demands are made on the waterproofing, not only to protect the supporting structure, but the pavement structure too and these render an appropriate level of quality necessary. This means that the service life of the waterproofing and pavement structure, must be determined and included in the consideration of life cycle costs [2].
- Taking into account the specific conditions pertaining, how long is the waterproofing of the bridge protecting the supporting structure to fulfil its function?
    - According to international standards: 50 – 60 years.
- How long is the bridge pavement to fulfil the demands placed upon it with full road safety provided?
    - According to international standards: 20 – 35 years.

2. WATERPROOFING AND PAVEMENT DESIGN

As far as the structure of the pavement is concerned, equating key structures with main traffic axes is unthinkable. An unique asphalt engineering is required for every single bridge / tunnel structure. Local conditions, actual location, traffic frequency and structural engineering make synchronized planning essential, particularly for larger structures. Specifics which substantially affect the evaluation of the system include:

1. Maximum air temperature in summer / minimum air temperature in winter
2. Maximum Delta T in winter with accelerated cooling down
3. Maximum variation in length of the supporting structure in summer compared to winter
4. Expected traffic frequency (TF)
5. Increase in traffic over the next 25 years
6. Percentage share of heavy vehicles
7. Max. axle weight of vehicles
8. Number of days with application of de-icing salt
9. Number of winter days with minus temperatures below -10° C
10. Max. longitudinal gradient
11. Max. transverse gradient
12. Designed speed

Where sophisticated structures are concerned, good products, well-matched to each other, are not sufficient to fulfil the requirements specified for the individual structure. The compatibility of the systems plays a significant role. Therefore for example, a bridge pavement construction consisting of waterproofing and pavement should not only be bonded to the whole area when it is installed, but should remain bonded prove over the complete service life. Since extreme traffic loads can also be transmitted to the supporting structure of the bridge, all layers must remain permanently bonded together. This in turn calls for special asphalt surfaces which are impermeable; precipitation / salt water as the case may be, must run off into drainage ducts. The complete pavement section should remain "dry" in order to achieve the longest possible service life.

Particularly where bridge structures with longer overall lengths are concerned, variations in length caused by changes in temperature can be enormous; in a summer to winter comparison these can be up to 250 cm. Longitudinal compensation is primarily achieved with the use of dilatation joints. The expansion and contraction cycles of these must also be taken up by the waterproofing and pavement construction. If one considers a service life of waterproofing and pavement construction to be 25 years, it results in ≥15,000 contraction and expansion cycles, calculated on the basis of 25 years for larger bridge structures in central Europe. For bridges with an overall construction length of >1000 metres, this results in around 20% of the movements being > 50 cm. Thus it can be seen that extremely high demands are placed on the waterproofing and pavement construction [3].

3. PROTECTING THE SUPPORTING STRUCTURE

The supporting structure must be pre-treated to ensure that the selected sealing can be bonded to the complete area.

Concrete bearing plates are to be cleaned by shot or sandblasting. A bonding agent and an epoxy sealant / filler is applied to the cleaned surface.

Steel bridges are cleaned by shot blasting. As the work progresses, application of corrosion protection / primer immediately follows. In any case, it is absolutely vital to ensure that between shot blasting and priming, no corrosion is able to take place.

The sealant must protect the bridge structure at least until the top course / binder layer is scheduled for repair as part of normal maintenance procedures. For fully-bonded sealers applied by spraying, for example liquid plastic based on PMMA (Polymethyl methacrylate), a service life of up to 50 years is expected. Again, this means that the protective / base course is also to be designed with a substantially longer service life and that the structural dimensions of the pavement be such, that maintenance work can be restricted to changing the top course only.

4. BRIDGE PAVEMENT

The type of bitumen bridge pavement system is basically dictated by the bridge specification and environmental considerations. The design of bridge pavements are technically different than for overland highways. As a rule, pavements on overland highways which are designed and constructed to standard, achieve a service life of 15 years. If the identical pavement were to be used for a bridge, the service life would be significantly shorter, since pavements on a bridge are subject to more extreme loads (temperature influences, length variations, vibrations of the bridge structure) caused by traffic (inclusion of water etc.). AC pavements are not able to be easily or evenly compacted [4]. The following conclusions can be drawn:

4.1 Composite construction

A bridge pavement must remain permanently bonded to the waterproofing over its complete area and for the whole of its service life.

4.2 Variations in length

Changes of the supporting structure, sometimes extreme and occurring on a daily basis, make increased demands upon the pavement construction. This must be capable of absorbing the movements over the whole of its service life, without negative effects.

4.3 Thermal shock

Bridge pavements heat up significantly faster than those of overland highways, but also cool down faster. In winter, bridge pavements can heat up to +20 °C and within 4 hours cool down again to –20 °C. These extreme thermal-stress cycles subject the pavement construction to the highest demands, making it necessary to use only the best quality binders, minerals and additives.

4.4 Density

To ensure the long-term quality, the pavement structure should be as dense as possible, to allow precipitation and salt water to drain off the surface. Pavements with porous courses which absorb water, are subject to a fast aging process, since it is not possible for the water to seep away underneath. As far as a bridge pavement is concerned, the density of the construction should be a priority, to ensure the long-term quality.

4.5 Installation

Compaction of the pavement construction on bridges after AC courses have been laid is fundamentally problematic. Use of vibrating compactors is practically excluded. In addition, when compacting AC courses, other density values are obtained in the centre of the span than at the load-bearing supports.

4.6 Smoothness of the pavement

The evenness of a bridge pavement should be within tighter tolerances than that for an overland highway. Irregularities in bridge surfaces cause additional static loads in the supporting structure. With AC pavements this is a difficult proposition. On the one hand, for statics considerations, pavement constructions are selected which are as thin as possible, on the other, the supporting structures exhibit substantially more unevenness than overland highways do for example. Compensating unevenness on bridges is practically impossible using AC pavements.

4.7 Additives for MA

In order to construct stable bridge pavements which at the same time ensure greater flexibility at low temperatures, the use of special certified additives is called for. Although there are limits for mixing additives with rolled asphalt, mastic asphalt courses can be better refined with additives during their preparation.

5. THE NEW GENERATION MASTIC ASPHALT AS A BRIDGE / TUNNEL PAVEMENT OF SUPERIOR QUALITY

The development of mastic asphalt pavements since 1945 has been rapid. Pavements on high-speed highways, in tunnels and on bridges had opened up a broad-based area of application. The German standards formed a good basis upon which to continue the development of mastic asphalt. Various research projects linked to on-site experience, produced continual improvement in the production of mastic asphalt pavements. Thus, for example since 1980, mastic asphalt in combination with polymer-modified binders has been successfully utilized on large-scale projects in Switzerland. The result was pavements on autobahns, city highways, bridges and in tunnels, which after almost 30 years in service and in spite of maximum loading, currently still meet their requirements. 1990 marked the start of new research projects aimed at further increasing the stability of mastic asphalt at elevated temperatures, whilst at the same time obtaining improved low-temperature flexibility [7]. With the admixing of additives and using special minerals, the new generation of mastic asphalt was created. The principle is crucial:

> Density of coarse and fine aggregate particle layers to be as high as possible in order to use the smallest possible amount of binder for filling the cavities [5].

Consequently the importance of the mortar properties can be seen

- Choice of weak setting filler / ground limestone to improve the workability of the mastic asphalt
- Stronger setting filler / - (mixture) to increase stability in hot conditions
- Harder type of binder to increase stability in hot conditions
- Selection of special bitumen (e.g. Nynas) and / or addition of waxes, to improve the workability and at the same time, increase the stability in hot conditions [6]

Table 1: Class 0 - 11 mastic asphalt for top performers

	Mastic asphalt from Germany 1960	Mastic asphalt 1980s	Mastic asphalt new generation 2011
- **Binder content**	7.5	7.2	6.87
- **Binder grade PEN**	B 45	PmB 40 / 50	PmB 20 – 35
- **Softening point**	60.1	70.5	78.6 %
- **Supplements**	2.0 (TR)	1.5	0.13 %
- **Additives**	-	-	0.21 %
- **Static penetration**	3.1	1.95	0.71 / 0.89
- **Dynamic penetration**	-	-	1.14 / 1.54
- **Resilience**	-	-	53 %

The installation technology was highly significant for the further development of mastic asphalt.

5.1. Transport

In the transportation field it was recognized that new developments were required for using mastic asphalt transporting boilers. This led to the prevalence of horizontal mastic asphalt boilers (boilers with horizontal agitator) with improved power output and automatic temperature regulation, as opposed to those with vertical agitators. With these boilers, less instances of separation occur and this is a decisive factor for the new generation of mastic asphalt pavements with high chippings contents.

5.2. Paver

The quality specification for evenness handicaps the use of tracked pavers. In order to meet the requirement for improved evenness and above all, to be able to obtain a uniform thickness for the top course, the use of rail-mounted bulk pavers has come to the fore. Bulk pavers which have a weight of at least 4t per meter installation width, are necessary for planar installation of the new generation formulations of mastic asphalt, which are extremely stable.

5.3. Course compensation

The rail track provides decisive advantages for the quality of the top course. Before installation with the bulk top-course paver, the pass can be simulated using the special rail-mounted test beam. This is above all extremely important for bridges where unevenness must be compensated. Using the practically whole view of the mastic asphalt thickness (protective, supporting and top course), it can be ascertained where reprofiling is required or an additional mastic asphalt course necessary. All uneven places in the sub-structure, as far as and including the binder course, are recorded. Thus installation of the mastic asphalt top course with a specific course thickness (+/- 2 mm deviation) is possible and the specified planar values for the top course conformed to. The precision installation provides excellent conditions for repair works. Replacement of the mastic asphalt top course where it has been originally installed using a rail-mounted bulk paver, is unproblematic.

Image 3
Mastic asphalt paver

5.4. Surface treatment

Rail-mounted pavers can be synchronized with a rail-mounted surface finishing machine. By this means anchoring of the top chippings into the mastic asphalt surface is improved. Depending upon size, amount and type of chippings, it is possible to create a noise reduction mastic asphalt surface. Due to the improved anchoring of the top chippings, long-term behaviour also has a positive effect on road safety.

Image 4

Rail-mounted mastic asphalt surface finishing machine is beneficial for road safety and noise reduction

Image 5

Before installation of the protective course, the total pavement thickness is determined using the test beam. With this, the minimum and maximum thickness of the pavement structure is determined and this serves as a basis for planning the installation with respect to the number of layers and their minimum and maximum thickness.

Image 6
Mastic asphalt surface

6. SUMMARY

6.1 If sensitive civil engineered structures such as bridges, tunnels and high-speed highways are to have a good rate of availability, a superior quality is required.

6.2 When planning the pavement, particularly for key structures, life cycle costs must be taken into consideration.

6.3 The development of AC and mastic asphalt pavements during recent years has been considerable. The quality requirements for binders, supplements and additives are decisive for improving the quality of bitumen pavements. Particularly relevant are the stability behaviour and low-temperature flexibility.

6.4 The specifications of the European standards make higher quality for planning and installation necessary. For this purpose the system compatibility of composite layers and the evenness of the individual installed layers, play a significant part.

6.5 The top course should have a uniform thickness to provide good conditions for later maintenance work.

6.6 By using a rail-mounted surface-finishing machine, good conditions for road safety and noise reduction can be achieved.

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