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# Building Roads in Kurdistan: Pavement Performance Specification

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**Abstract:** In recent years, the principles of quality control and quality assurance in road construction and maintenance have come to be increasingly based on the performance or function of the asphalt layer and/or its surface characteristics. It is valuable to be able to use the functional material properties in the quality control of bituminous layers, and to relate the layer's properties to the pavement performance. Traditional or empirical specifications are based on the client's description of the product; the contractor is told exactly how to do the work. These specifications are called method or recipe specifications and quality control is based on empirical methods and engineering judgement. The road specifications used in Kurdistan Region of Iraq, based on engineering judgement and empirical testing methods, could be classified as a traditional recipe specification. An overview on the principle of the performance specifications used in different industrial countries is presented in this paper.

***Keywords:*** *Pavement, bituminous layers,*

## Introduction

The road network is very important to a country's economy and social growth and it needs an efficient management system. Increasing traffic volumes and a growing number of road safety issues require sustainable construction techniques and a well-maintained road network. Traditional specifications are based on the client's description of the product; the contractor is given precise instructions on how to carry out the work. These specifications are called method or recipe specifications. Quality control is based on empirical methods and engineering judgements, with less attention being paid to variability in material properties and construction characteristics. Recipe specifications are not directly related to the performance of road pavements. In recent years, there has been a growing need for performance specifications which focus on pavement performance over time. Performance is described in terms of changes in surface characteristics, mechanical properties of pavement layers, or pavement response to traffic loads. Performance-based contracts should result in a more cost-effective road network.

In recent years, the principles of quality control and quality assurance in road construction and maintenance have come to be increasingly based on the performance or function of the asphalt layer and/or its surface characteristics. It is valuable to be able to use the mechanical/functional material properties in the quality control of bituminous layers, and to relate the layer's properties to the bituminous layers' structural performance. It is also essential that the test procedure takes into consideration the effects of production, laying, and compaction of asphalt mixtures. The procedure must both be suitable for routine use and sufficiently reliable to be used in the specification for asphalt mixes. The use of mechanical properties in the specification of mixes will help establish a relationship between mix design and pavement design, and in turn link specifications directly to performance.

The road specifications used in Kurdistan Region of Iraq, based on engineering judgement and empirical testing methods, could be classified as a traditional recipe specification [1].

An overview on the principle of the performance specifications used in different industrial countries is presented in this paper.

## Definition of performance specification

The term performance or functional specification is often used flexibly. However, for the purpose of this report, these terms are used as defined in the PIARC report [2]:

- performance specification: one that describes how the finished product should perform over time. For highways, performance is typically described in terms of change in physical conditions of the surface or its response to loads, or in terms of the cumulative traffic required to bring the pavement to a condition defined as failure;
- performance-based specification: one that describes desired levels of fundamental engineering properties (e.g. resilient modulus, creep properties, fatigue properties) that are predictors of performance and appear in primary performance prediction relationships;
- performance-related specification: one that describes desired level of materials and characteristic factors that have been found to correlate with fundamental engineering properties that predict performance. These factors are amenable to control and acceptance testing at the time of construction.

## Pyramid of specifications

The pyramid of specifications or pyramid of demands is a very useful method to understand the principle of road specifications [3]. The pyramid distinguishes different levels of demands, as shown in Figure 1. The lowest level is based on the identification of the properties of the raw materials used in road construction. However, the highest level is based on user demands and can also be of use in the strategic planning of public services.

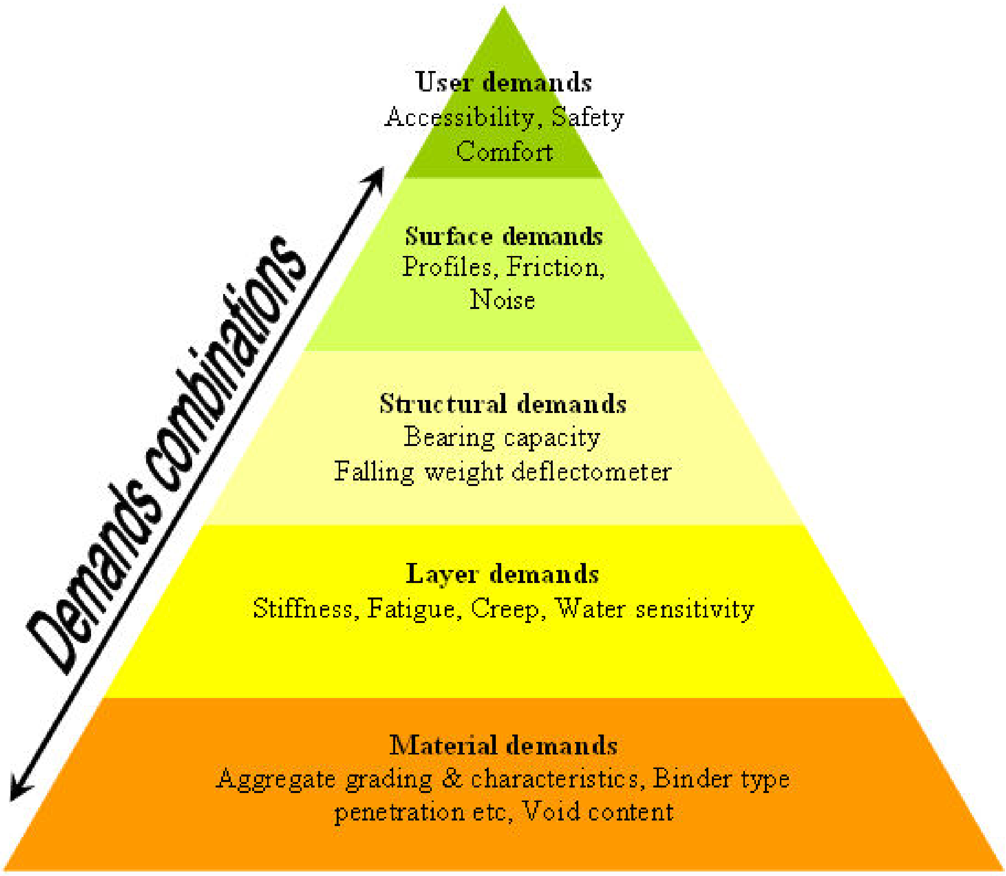


Figure 1: A pyramid of specifications.

Requirements at the lowest level, Material demands, describe the properties of the raw materials used in road construction, such as the rheological properties of bitumen, aggregate texture and resistance to crushing, the composition of the mixture etc. This level prevents the development in practice. The contractor is given exact instructions on how to do the work, what materials to use and in which composition, and the exact number of compaction roller passes. The quality of the work is specified indirectly at this level.

The Layer demands level describes the fundamental properties of the pavement layers, such as stiffness modulus, resistance to fatigue cracking, deformation and tensile strength, which are used in analytical pavement design. The desired quality level is also specified directly. The contractor is given freedom to select the technique to achieve the desired quality of the pavement layers.

At the Structural demands level, the interaction between pavement layers is also quantified. The bearing capacity of the road, which is related to its service life, is defined. This level can be used in the construction of new roads. The contractor can take responsibility for the pavement design and guarantee that the desired bearing capacity is achieved.

At the Surface demands level, the surface characteristics, e.g. evenness, friction, noise, cracking, and rutting, are defined in relation to elapsed time. The contractor is responsible for surface deterioration over time (usually > 5 years) or traffic volume. At this level, the contractor is usually also responsible for the maintenance of the road in order to maintain the surface characteristics at a satisfactory condition.

At the highest level, User demands, the road user requirements are priced, e.g. road safety, accessibility, travel time etc.

On the whole, road administrations in industrial countries are moving towards performance specifications and higher levels of the pyramid in developing contracts and specifications. The performance specifications are intended to result in a balance between cost and road construction quality.

## Principles in the Swedish road specifications [4]

Currently, performance or functional specifications define requirements in respect of asphalt layer or surface characteristics. This means requirements based on functional properties which describe the function of a product that is directly or indirectly related to traffic safety, accessibility, comfort, the environment, and life cycle costs. The Swedish performance specification can be classified as a combination of performance and performance-based specifications according to the definition in PIARC Report [2]. The limits of the functional or performance parameters correlate to the design traffic and climate. It is noteworthy that the empirical specification based on material demands are still in use, but a growing number of contracts every year are now being based on performance specifications.

## Structural requirements based on asphalt layer characteristics

The idea in the specification in respect to performance or function is to define requirements for each layer rather than for mixes. For example, a base layer must fulfil some requirements in respect of traffic loading and climate conditions, such as resistance to fatigue cracking. The Swedish specification does not, however, dictate which types of mixes must be used in base layers. The problem is that not all types of mixes can be evaluated by mechanical means and/or by taking specimens from pavement layers, as is the case with thin bituminous layers. Therefore, in these cases, it is permitted to manufacture specimens in the laboratory. Laboratory-manufactured specimens, however, are subject to more stringent requirements in order to ensure adequate asphalt concrete. To cover the most frequent structural distresses in the field, the specification guidelines for asphalt concrete should at least include test procedures for flow rutting, fatigue cracking, stiffness, wear, and water sensitivity that are relevant to Swedish conditions. A description of the most frequent testing procedures is presented below.

## Stiffness modulus

Flexibility and load distribution capacity are two important characteristics of bitumen bound layers. High-stiffness bituminous layers protect underlying layers through better stress distribution, resulting in less stress being applied to the underlying pavement layers. Low-stiffness bituminous layers are flexible and desirable in thin pavement structures with low traffic loading, where the purpose of the asphalt layer is not primarily to increase the bearing capacity of the road, but rather to increase riding comfort and safety and to protect underlying layers. Stiffness of bituminous layer is one of the most important parameters in analytical pavement design.

Stiffness modulus is measured on cylindrical cores from asphalt layers using Indirect Tensile Test and according to the Swedish standard, FAS method 454 [5], see Figure 2. The effect of age has been found to be very significant, especially during the first year after laying. The following regression equation can be used to calculate the stiffness modulus of the asphalt concrete layer in respect of age. This relationship is based on a number of cores taken from pavement layers on different occasions over a five-year period [6].

$$S_{t_2} = S_{t_1} \cdot (t_2 / t_1)^{0.08}$$

where

| | |
|---|---|
| $S_{t2}$ | is the stiffness modulus at $t_2$ in MPa |
| $S_{t1}$ | is the stiffness modulus at $t_1$ in MPa |
| $t_1$ & $t_2$ | are the age of the bituminous layer in months |

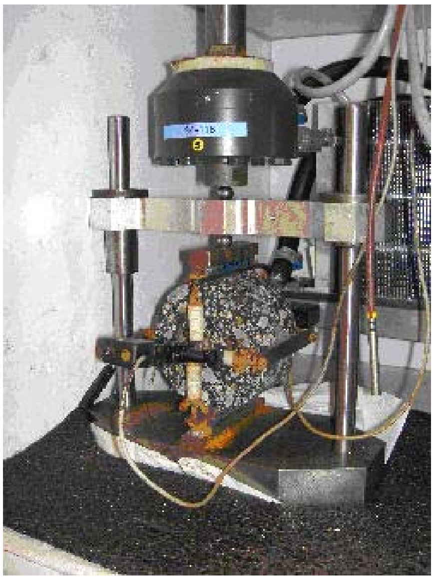

Figure 2: Indirect Tensile Tests

The stiffness modulus of a one-year-old pavement layer has been taken as the initial stiffness modulus in evaluation of bituminous layers. The structural functional characteristic requirements with regard to the stiffness modulus of pavement layers are shown in Table 1. These values are based on earlier measurements on cores from existing pavement layers, which were normally about 1 year old.

Table 1: Stiffness modulus requirements in mega Pascal (MPa).

| Layer | $AADT_{1,heavy}$ | Stiffness Modulus for the base course in MPa | | |
|---|---|---|---|---|
| | | +5°C | +10°C | +20°C |
| Surfacing | All | < 9 000 | - | - |
| Binder course | All | < 11 000 | 5500 - 9 000 | - |
| Base course | > 1000 | < 11000 | 5500 – 9000 | > 1500 |
| | 200 – 1000 | < 11000 | 4500 – 7000 | > 1500 |
| | < 200 | < 9000 | 2200 – 7000 | > 1500 |

## Fatigue cracking

Fatigue failure of a bituminous layer means the development of cracks in the pavement layer caused by repeated traffic loading. Fatigue testing is time-consuming and it is known that the fatigue property of asphalt concrete is well correlated with the stiffness of the material. Therefore, fatigue testing is only recommended when using new type of mixes (not tested before) or if there are particular reasons. Requirements with regard to the fatigue resistance of asphalt layers are based on traffic volume and the stiffness modulus of asphalt concrete at 10°C, see Table 2. The permitted tensile strain at specified traffic volume is calculated from the fatigue criterion of bituminous mixtures that in turn depends on the stiffness modulus of the asphalt concrete layer. The fatigue criterion in the Swedish specification is based on laboratory measurements made on cores and calibrated with the field-based criterion. The fatigue relationship can be used instead of the requirements in Table 2.

Table 2: Tensile strain requirements with respect to fatigue cracking as a function of design traffic.

| $AADT_{1,heavy}$ | Tensile strain at $10^6$ loading in $\mu\varepsilon$ at 10°C | | |
|---|---|---|---|
| | Base course | Binder course | Surfacing |
| > 1000 | > 80 | | |
| 200 – 1000 | > 100 | > 60 | > 80 |
| < 200 | > 130 | | |

## Flow rutting

In spite of the cold climate in Sweden, flow rutting is one of the most frequent types of distress in high-volume roads. This is primarily due to the use of softer binders. The resistance of asphalt concrete layer to flow rutting is measured on cylindrical cores of the pavement layer using the Repeated Axial Creep Test according to the Swedish Standard, FAS

Method 468 [7], see Figure 3. The structural functional characteristic requirements in respect of the flow rutting resistance of the asphalt pavement layers are shown in Table 3. However, due to practical difficulties, no requirements are stipulated for bituminous layers with a thickness less than 25 mm. Bituminous layers with a thickness of 25-40 mm may be tested on specimens compacted in the laboratory after approval by the National Road Agency. These requirements are based on earlier experience of using creep tests on cores. As with the stiffness modulus, the effects of age have been found to be very significant for the creep results. Therefore, a similar relationship has been determined for creep tests. The following equation can be used to calculate the creep deformation of the asphalt concrete layer with regard to age [6].

$$D_{t_2} = D_{t_1} \cdot (t_1 / t_2)^{0.23}$$

where

$D_{t2}$ is the permanent strain at $t_2$ in με
$D_{t1}$ is the permanent strain at $t_1$ in με
$t_1$ & $t_2$ are the age of the bituminous layer in months


Figure 3: Creep test

Table 3: Requirements on creep deformation as a function of design traffic

| $AADT_{1,heavy}$ | Permanent strain in $\mu\varepsilon$ | | |
|---|---|---|---|
| | Surfacing | Binder course | Base |
| Extreme load | < 15000 | < 12000 | < 18000 |
| > 2000 | < 18000 | < 15000 | < 21000 |
| 1000 - 2000 | < 21000 | < 18000 | < 25000 |
| 500 - 1000 | < 25000 | < 21000 | < 30000 |
| 100 - 500 | < 30000 | < 25000 | - |
| < 100 | - | - | - |

## Water sensitivity

The durability of bituminous layers, especially against the effects of water and moisture, is one of the most serious factors contributing to the degradation of asphalt pavements in Sweden. Freeze-thaw conditions also have the potential to lessen the cohesive strength and stiffness of the asphalt layers. The water sensitivity of asphalt concrete is determined by testing cylindrical cores of pavement layers using the Indirect Tensile Test. The Indirect Tensile Strength Ratio, ITSR, (adhesion value) is obtained as the ratio of the tensile strength of conditioned samples to that of unconditioned samples according to the Swedish Standard, FAS Method 446 [8]. Bituminous layers with a thickness of less than 40 mm are to be tested on specimens compacted in the laboratory. The specimens shall be compacted to the air void content expected in the field, and the ITSR value must be larger than 75% for bituminous layers.

## Functional requirements based on surface characteristics

Requirements based on surface characteristics are mainly correlated with traffic safety and riding comfort. The surface characteristics, for example evenness, friction, noise, cracking, rutting (transversal profile), permeability, texture, cross fall, and stripping, are defined in relation to elapsed time. The contractor is responsible for surface deterioration over time, which is usually a period longer than five years. It should be mentioned here that much effort has been put into evaluating variability and establishing acceptance limits. The requirements with regard to road surface characteristics are usually related to road type, traffic volume, environmental parameters, and the object's historical data. At the present time, there is no limitation in the specification in respect of surface characteristics.

## Comments and recommendations

Increasing traffic volumes, a growing need for improved road safety, better protection of the environment, and the need for more sustainable roads at less cost, have given rise to a necessity for more efficient construction techniques, where all partners, clients and contractors share the risk. This leads to a need for sufficiently competent staff to design and construct the roads in order to guarantee the desired quality level at minimum service life cost. Most industrial countries have now adopted one or more types of performance/functional specifications to be used in road contracts. In many cases, the performance specifications adopted into contracts are a combination of performance and performance-based specifications. However, during a transitional period, traditional approaches (recipe specifications) are still in use in parallel to performance specifications. This is also the case in Sweden. The Swedish performance specification permits a high degree of freedom on condition that client and contractor can reach agreement. The procedure is relatively simple, useful, and practical, but it still needs a great deal of development in order to be a complete performance specification. The specifications used in the Kurdistan Region of Iraq are traditional specifications, where the contractor is told exactly what materials to use, in what proportions, what mixing procedure to use, what construction equipment to use, and how laying and compaction are to be done in the field. The engineering judgement plays an important role in producing a product with a satisfactory quality level.

To fully understand the advantages of performance specifications, a pilot study using full-scale pavement sections could provide valuable information and experience. Such an activity should be preceded by some investigations and trials at university level with the cooperation of the National Road Administration and interested contractors. The choice of level depends on the knowledge, competence and experience of the client and contractor in the country of interest. Introducing a type of performance specification in the Kurdistan Region of Iraq should help in achieving a desired quality level in road work, and in such a way that road owner costs, user costs and safety issues are considered.

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