Functional specifications for road pavements - a question of risk assignment

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Introduction

Throughout the world, clients and contractors are investigating functional specifications. Asking questions such as, what are functional specifications? And why use functional specifications? Further, do we understand each other when we talk about functional specifications? Based on experience and international work the author is convinced that a conceptual approach is missing from discussion on functional specifications.

There is misunderstanding between specialists, due to a lack of semantic clarity. Functional specifications are not new, they are used internationally; otherwise road building would not take place. What is new is that functional specifications will be used increasingly in contracts on a variety of different levels. This paper presents a conceptual approach that might enable those involved in functional specifications to better understand their own work and the work of their colleagues. This paper also explores some potential consequences of different forms of functional specification.

What are functional specifications?

Although you might expect to find a definition of functional specifications that will satisfy all questions, this will not to be given. Both nationally and internationally, people disagree on the definition. It is not the goal of this paper to present a definition. The concept of functional specifications will be discussed, leaving the question of a definition to others. In general, one could say that it refers to specifications that have a relationship to a particular function. This does not mean anything. First, one has to define which object the function is referring to and then assess the complexity of the system. For example, the function of a road is more involved, than the function of a piece of sand in an asphalt mixture. Nevertheless, both fulfil a function and for both specifications can be, and are, drawn up that relate to their functions.

Pyramid of demands

As a tool to define demands (e.g. user demands or construction demands) through specific qualities, the 'pyramid of demands' can be used (See Fig 1). This model is used in the Netherlands. In practice, the whole world uses this model, although one might not be aware of it. The purpose of a road is that it satisfies the needs of the customer within a framework of political, economical and environmental demands. The road engineer is able to build such a road using all kind of models. The pyramid is a way of showing the relationship between the highest level (a connection between A and B), and the requirements for raw building materials on the lowest level (e.g. grading). In this pyramid, several levels are distinguished.

In this example an asphalt road is used, but the approach is valid for all types of construction:

Example based on an asphalt road

On the highest level, one could ask for a road that is able to transport people and goods in a comfortable and safe way, for a certain traffic volume and travel time, in harmony with environmental goals. Based on traffic models, one can calculate how many lanes are needed. Safety models can define geometries and surface characteristics. The construction can be examined using a construction design model. The input parameters for our models are axle loads, traffic flow (present and future), design life, climatologically and geometric conditions and material properties. Using material models, the material specialist can design mixtures that will fulfil the parameters used in the design model. These material models will also examine other needed material parameters such as deformation resistance and durability. Which are not normally used in a constructive design model, but are relevant for the design life of a construction or wearing course.

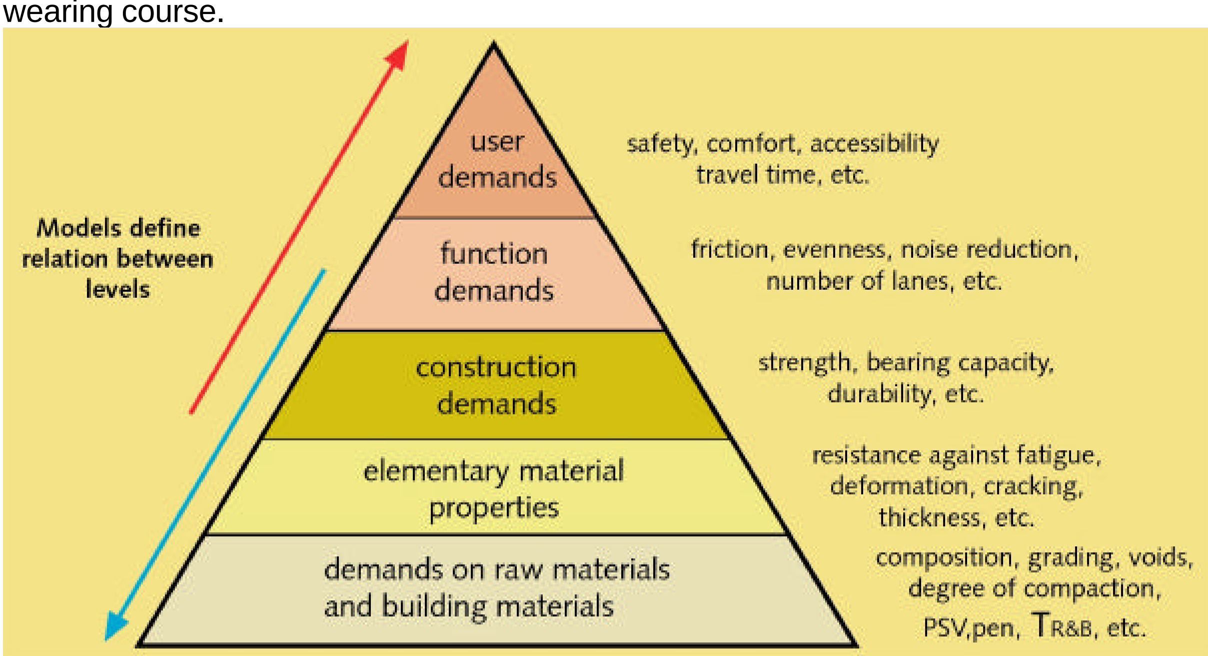

Fig 1 Pyramid of demands

By using these models we are able to show that in practise, the road engineer is able to determine requirements down to the lowest level (based on demands on the highest level which are generally a compromise between different political goals). Conversely, using requirements on the lowest level will guarantee that a road will perform as expected at the higher levels. The relationships between the different levels can be illustrated means of models. One example is the construction material mix design method for the relationship between level 5 and 4. Therefore if specifications are made on the lowest level (including production, laying and compaction requirements) asphalt mixtures with specific functional properties (fatigue, stiffness, deformation resistance, etc) are produced. Another example is the construction design method for the relationship between level 4 and 3. Construction design models calculate the thickness of a road, to fulfil its bearing capacity for a specified traffic volume over a desired lifetime and having sufficient surface characteristics to make a journey as comfortable and safe as possible.

There are relationships between and within all levels. Therefore, in defining e.g. the life of a road, one uses (expected) maintenance and rehabilitation models based on the known behaviour of the materials. For instance, if one knows by experience that the life of a wearing course is approx. 10 years, one can decide to have a design life of 20 years. So after 10 years, resurfacing and after 20 years, re-strengthening (of course, the choice of the design life also depends on other criteria).

This so-called pyramid of demands reflects the way a specification and design system is built. It is a concept that can be applied internationally.

In general, all road designs use functional specifications. We all design and construct roads that fulfil requirements set at the highest level on the pyramid of demands model. Generally it is the client who using these models under various political, environmental and economic considerations puts a contract on the market. These prescribe (at the highest level) what to build and (at the lowest level) define materials and production specifications. All product standards reside on the lowest level. The material specifications in general will provide mixtures that will meet the design life. These specifications include requirements for raw building materials, production, laying and compaction requirements.

Therefore we use functional specifications and between each level of the pyramid information is exchanged between different parties. Within each level specialists are capable of defining and detailing the request of the higher level to more particular specifications.

Requirements on all levels can be different due to national priorities, financing systems, maintenance criteria, economical considerations, climatic circumstances, quality of natural raw materials and safety considerations.

If one recognises the system, it is clear that in fact all the requirements used on each level of the pyramid, have a relationship with the function of the final road (if there was no relationship there would be no need for a specification). One can view the total pyramid, including all models and specifications, as the condensed knowledge of decades of experience of road construction. All over the world, different models are used and therefore different specifications apply. However, one has to realise that models only describe existing knowledge. In fact, many models are empirical in such a way that they are validated for the materials used in practice, therefore once outside the bounds of empirical knowledge the models lose their validity. At present the majority of discussion concerning functional specifications refers to the need to specify a contract on a higher level than the bounds of empirical knowledge permit. This changing approach is stimulated by different evaluations as will be explained later. Specifications set out in a contract require a system of assessing quality through empirical test methods at specified intervals.

A changing approach.

What are the reasons for this changing approach? If the system is satisfactory as described above, why is there a need? A few reasons follow:

- The changes in materials usage are great. New demands for the performance of materials require that new materials be developed. There is less experience of working with new materials and there fore the risks involved are greater. We do not know the future behaviour of new materials, but we would like to implement potentially better materials as soon as possible. The recycling of materials can imply higher risks. This means that the existing models give an insufficient guarantee of behaviour, and greater level of security is needed.

- Changes in contractual relationships. For several reasons, clients are putting contracts on the market, transferring tasks traditionally done by the client, to the contractor. The reasons why, are out of the scope of this paper. The pyramid of demands illustrates that in general, it is possible to define requirements on each level, and put it in a contract on the market.

Risks

In fact, there are many countries experimenting with different contracts defining their requirements on different levels of the pyramid. E.g. design, build, maintain and operate contracts, defining for instance a 30 year maintenance and operate period are contracts on the second level. Contracts requiring certain material properties such as deformation resistance or fatigue properties can be defined as contracts on level four. In principle, there is no objection to this. When a client can design a road why should a contractor be unable to do so, when he uses the same models, the outcome will be the same.

Here is where the uncertainty starts. There are many uncertainties that involve risks for both parties. Consider a 30-year DBM contract? With whom do the greatest risks lie? One could say this is the safest contract for the client. Conversely, a 30-year period is very long. What are the consequences when within those 30 years there is a change in demand for that road? In the Netherlands, the requirements set on roads have changed significantly over the last decade, which means that the contract with the contractor has to be changed during the contract time.

Is one able to define all relevant requirements? What risks are involved with the material properties? As stated previously, models give the relationship between the different levels of the pyramid. These models are by nature highly empirical. This means they only provide satisfactory answers when one stays within the limits of that empiricism. For example the temporally changing nature of cement in concrete might result in a constant compressive strength but different durability properties. Determining Marshall properties for a new mix such as porous asphalt can give results that cannot be implemented in the existing expertise and provide another example of the empirical nature of existing models. One of the reasons for specifying on a higher level is to give a contractor more degree of freedom, which may lead to innovation. However, innovative products and techniques are out of the bounds of empirical knowledge and therefore there are risks involved. For contractual situations, it is necessary to define who is responsible for the risks implied. The method of assigning risk differs from country to country.

Production reality

Let us consider the process of constructing a road. This process is independent of contract type. For example the process of the bituminous or concrete mixture production will not change with contract type. In all production processes there are control mechanisms needed to ensure that a product fulfils requirements. The question is, where in a production process should one measure. Road construction deals with natural materials with inherently fluctuating characteristics. Fig 2 illustrates different possibilities.

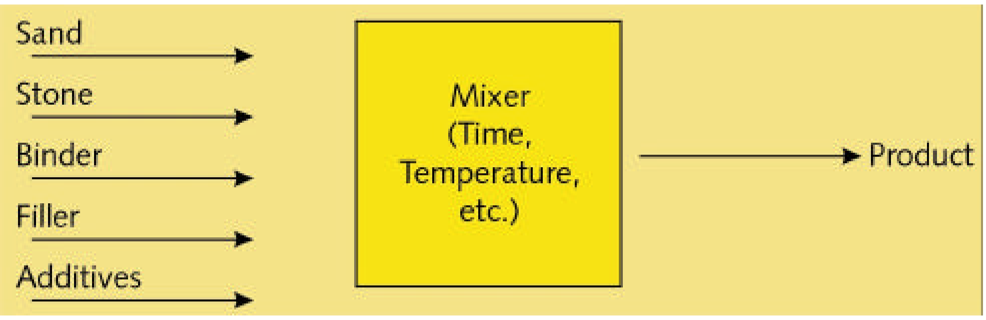

Fig 2 Mixture variability

The product has to fulfil specific properties. On a high level these are properties such as durability, fatigue properties, stiffness properties, deformation resistance. In an empirical approach, the producer knows which mixture he has to produce, controlling incoming materials, grading, amounts, mixing time, temperature etc. Meeting the construction demands and controlling the mixture composition are enough to fulfil functional properties. He does not measure the functional properties because they do not allow him, given the time required for these tests, to control and adjust his production. Besides that, he should know to what extent the different parameters influence the functional properties. This implies adequate models, which do not exist. Therefore a producer cannot do anything else than what he has always done, that is to control a recipe.

The other side of this coin is that one cannot ask for levels of properties that are not realistic. Figure 3 shows that when starting with a specific mixture (determined by mix design, type testing) due to factors that influence the properties (production: temperatures, mixing time, etc.; laying and construction: transport, compaction, temperature etc.; and service life: climate, traffic etc.), the functional properties will change and give variability in the final product. This is a natural phenomenon with which (by experience) we know how to deal. Through results from observed inter decadal changes in material properties; we have been able to specify production, construction and material parameters. One could say that these requirements are satisfactory, otherwise we would have made alterations, and of course this is done on a regular basis.

Figure 3 can be interpreted differently. If the spread in properties is what we have today, when we are able to control that spread, it is not possible to specify in a contract, a smaller spread than that is achievable. For that would imply that the contractor knows how to control his production to narrower specs. As has been stated before, there are no models for him to follow. Maybe we have ideas on the reduction of spread, by use of better-specified materials or not permitting production under certain weather conditions, for example. If we think such amendments are relevant and important for the behaviour of the material, then we can amend the standard regulations now.

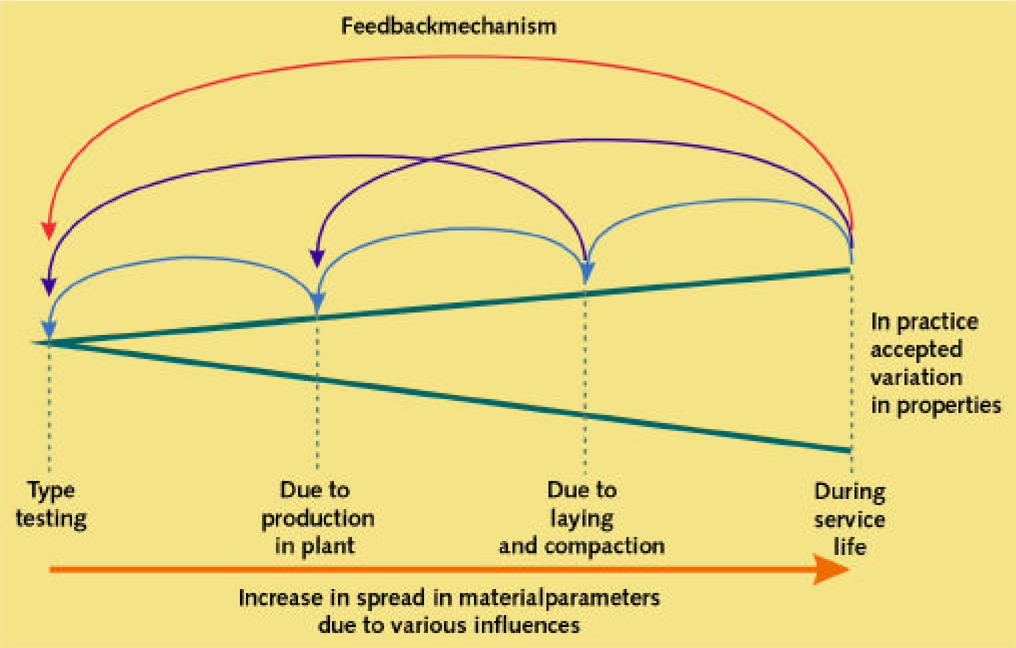

Fig 3 Feedback mechanism

Models are only a description of reality. They do not represent the total truth. For instance, requirements for some mechanical properties such as fatigue or deformation resistance only address some but not all relevant properties that determine actual performance with time. Remember also that often the time dependency is not measured but, on experience, is taken for granted. Fulfilment of a requirement on a certain level does not automatically mean that performance is the same when the mixture is totally out of our empirical expertise. Should a material lay outside of our empirical expertise often a combination of empirical requirements (such as type of mixture etc.) and more advanced mechanical testing is used.

Fundamental properties

Countries are experimenting with what they call functional requirements and tests on a material level (level 4), for example stiffness properties, fatigue properties, deformation resistance etc. We know that these tests are not fundamental. What one wants to measure is a real material property, which should be independent of measurement method. In reality, the different tests used over the world do not give similar results. Experts also have differing opinions about which test to apply for which property. Does that mean that one is doing invalid measurements? Not necessarily, one has to look at the total system being used. It also means that the so-called more fundamental tests are empirical. Or recasting the previous sentence, such tests do provide information on a higher level but still in an empirical context.

Future outlook

Without a doubt, moving up to a higher level in contract relationships will mean that contractors gain more experience dealing with risks. Clients will be forced to rethink their traditional approach. More knowledge will increase quality to meet the growing complex demands put forward to roads, and is a good thing. It might also improve innovation. Initially through innovation in the process of construction, operation and maintenance. And later product innovation will be stimulated, although new products imply a higher risk as their future performance is not known. A well planned development and introduction is needed.

Several questions are raised by some of these new approaches and dealing with consequent responsibilities. Public clients have responsibilities to society. Depending on national regulations, they might also be responsible if anything occurs on a road. Planning of maintenance and disruption to traffic is a key issue, as far as maintenance contracts are concerned. Not forgetting the socio-economical and ecological importance of a road.

Functional specifications in a contract will improve the knowledge of both clients and contractors. One has to be aware of enhanced risks and determine how to deal with them. Greater risks for the contractor will be reflected in a higher price. It is not known what proportion of present contractor costs reflects these risks.

Summary

As has been stated before, the system for the production of mixtures and roads has not changed. What is changing is the relationship between contract partners. There is a transfer of responsibilities from the client to the contractor. This transfer of responsibilities has associated risks.

One of the reasons for introducing functional specifications is to stimulate innovation. Innovation means stepping outside the empirical models. Specifying in functional requirements is not new. What is new is that functional specifications of a higher level are introduced into contracts. Several levels can be distinguished, each level introducing other uncertainties and therefore risks. A conceptual approach like the pyramid of demands can facilitate the discussion.

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