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A Dutch example

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On the need for innovation in road engineering A Dutch example

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Abstract

In an ever faster changing world, innovation is a crucial tool to maintain the quality of road networks. In order to safely use innovative materials and techniques, validation procedures are needed. Because of the variable and non-standard nature of innovations, it is hard to standardize this kind of validation. Also, ensuring that innovations address the needs of road authorities can be quite a challenge. The Dutch highway authority, Rijkswaterstaat, currently uses a three tier approach to the validation of innovations. These consists of solicited innovations to address specific agency challenges and two systems to address unsolicited innovations. This paper describes the need for innovations, the most urgent topics that require solutions in the Dutch situation, the current approach towards innovation validation including examples of all three types of validation and the further developments foreseen for that system.

Keywords: changing conditions, innovation, validation

I. INTRODUCTION:

There is a lot of attention for innovation nowadays. Sometimes, it is considered a hype, but in reality innovation is a necessity, one of the means to ensure pavements can continue to fulfil the ever changing demands from society.

This shows that innovation is not an objective in itself, it is driven by the need to provide solutions to problems. Road authorities need innovation to allow them to build and maintain roads for increasing traffic numbers, with decreasing budgets. Contractors and material producers need to innovate to grow or at least retain market share by providing cheaper, smarter, or faster solutions without loss of quality.

In a world that is rapidly changing, all countries face their own challenges in this respect. Because although the trends that drive rapid changes are the same all over the world (Fig. 1), the way they manifest themselves varies. For example, climate change occurs over the whole world, but in some places this is mostly found in increased dry spells, others experience more storms and extreme rainfall and low-lying coastal areas face rising sea levels. So the global trends result in local challenges and changes.

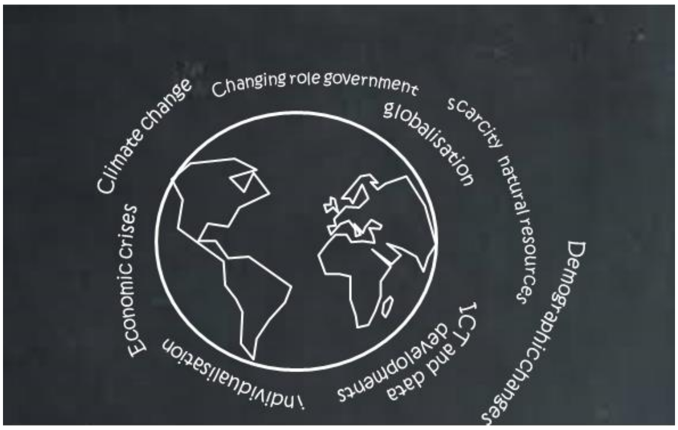


Fig. 1: worldwide trends that drive rapid changes

For the Netherlands, for road engineers are traditionally related to its high population density (Fig. 2), its location at the edge of the European continent (Fig. 3) and it's nature of river delta country.

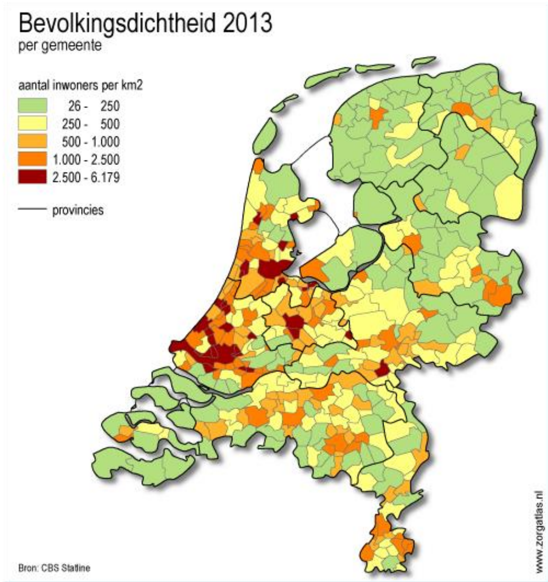


Fig. 2: Population density in the Netherlands in occupants per square kilometer

Its location makes it which makes it an important entry for trade to the European mainland, which results in high traffic intensities and loads, while its delta nature results in high water tables and poor soils.

Fig. 3: Geographic position of the Netherlands, at the edge of Europe

Accommodating large amounts of traffic on poor soils and densely populated area's is quite a challenge, but the worldwide trends add increasing variability to this known challenge. Because that is the effect of the trends:

- climate change leads to variation in the known weather conditions, in case of the Netherland a rising water table, more extreme events (like frost periods, heavy rainfall, snow and black ice) and eventually an increase in the annual average temperature. All in all this leads to changes in the weather conditions you design for
- the increasing lack of natural resources, which increases the price of both bitumen and aggregates, leads to changes in constituent materials and more variation in mixture composition. Since the Netherlands has no natural rocks, only river gravel, all quarry materials have to be imported
- demographic changes lead to changes in traffic loading and user requirements, in most of Western Europe overall population is expected to start decreasing in the current century and already the average age of road users in increasing
- globalisation leads to the use of new materials (bio-binders) and rapid developments of knowledge and regulations that have to be adapted or fitted to local conditions
- individualisation leads to reducing acceptance of delays due to maintenance as well as higher expectations of availability, quality and less acceptance of hinder for people living near (main)roads. This leads to a drive towards longer lasting materials, fast maintenance methods and noise reduction measures.
- the economic crisis and changing role of government have led to a decreasing maintenance budget
- changing government roles have also led to more responsibility for contractors and as a result, the ongoing practical knowledge on mixtures and pavements is now divided of more parties

All in all, these trends stand for increased variation in all aspects of pavement engineering. To withstand that variation and still offer good quality pavements, innovations are necessary. Also, a thorough understanding of the mechanisms affecting pavement performance is needed, because that will allow the assessment of the effects of changes without validations that last until the actual pavement failure.

II. The Dutch Approach to Innovation for Highways

The Dutch highway authority, Rijkswaterstaat (RWS), uses a three tier approach to innovation. On the one hand, there are large, government initiated and largely government financed innovation programs or calls. These programs or calls ask for solutions for problems and contractors or inventors can submit their ideas. Sometimes this is very open, a contest on concepts where the best ideas are further developed during the program and sometimes it is a more specific call, which quickly focusses on application and validation.

The second and third type of approach are unsolicited, someone has developed an innovation and want to apply it on the Dutch highways. In this case, they can contact Rijkswaterstaat and the originality of the innovation and it's benefits for Rijkswaterstaat are assessed. If the innovation is a truly new product or technique with benefits for Rijkswaterstaat, it is evaluated in the Innovation Test Centre (ITC). In this process, the developer and RWS specify and finance the program for validation together. If the innovation is not completely original, for example a similar approach has already been evaluated in the ITC or it involves a change in mixture composition that is not very large but does fall outside the established specifications, a validation specifically addressing that project has to be carried out. In this case also the program for validation is discussed between the developer and Rijkswaterstaat, but the program is more constrained and there is no financial contribution from RWS. The first two approaches are coordinated by the Rijkswaterstaat Corporate Innovation Program, the third is part of the department that sets the technical specifications for pavements and pavement materials. In the remainder of this section, examples of all three approaches to innovation are given.

A. Government initiated calls for innovation

Examples of calls for innovation are the "Roads to the Future" (in Dutch: Wegen naar de Toekomst, [1]), the "Innovation and Noise Program" (in Dutch: Innovatie Programma Geluid, [2]) and the "Long Lasting Silent Joints" (in Dutch: Duurzame, stille voegovergangen", [3]) programs.

In the first, innovative modular and pre-fab road construction approaches, like rolled up asphalt (Fig. 4), were developed and tested in practice [4 and 5]. The aim was to investigate pre-fabrication possibilities to decrease variation and increase speed of construction.

Fig. 4: Rolled up asphalt concrete

The Innovation Noise Program (IPG) focussed on the development and evaluation of the next generation noise reducing wearing courses. The combination of a high population density (average population density of over 400 people per square kilometre) in combination with high traffic intensities means that noise pollution due to roads is a major issue in the Netherlands (Fig. 5). For this reason, Porous Asphalt (PA), which results in a 3 to 4 dB noise reduction compared to Dense Asphalt Concrete (DAC), is the standard wearing course for Dutch highways since the late ‘80s . Although PA is more expensive then dense wearing courses, if using it means there are no, or lower, noise barriers needed, it is actually more cost effective.

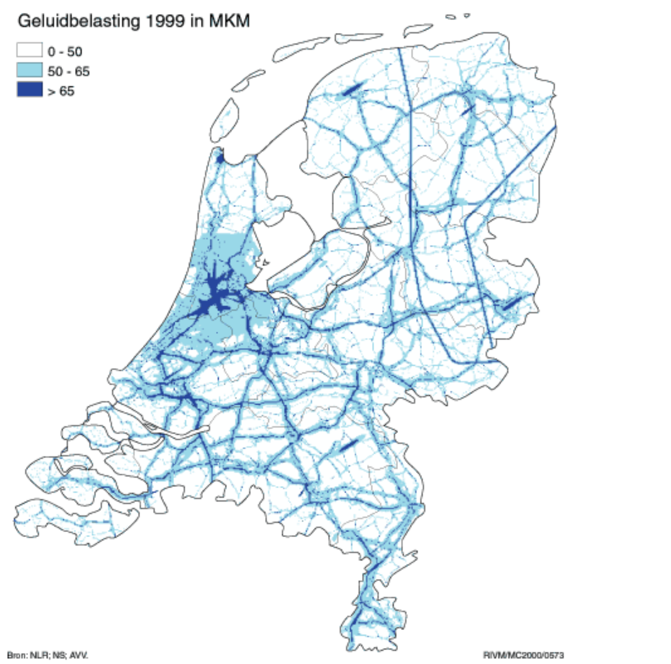


Fig. 5: Noise levels in the Netherlands in 1999, the dense spot center left is the Amsterdam-Schiphol area, the lines show the highways

In the beginning of the current century, for some locations along the Dutch highways, the noise level had increased to such an extent that standard PA was no longer sufficient. Hence the search for the next generation wearing courses, with even more noise reduction capacity. This resulted in two layer porous asphalt (2L-PA), which yield a noise reduction of 6 dB when compared to a DAC wearing course.

In the long lasting joints project (Fig. 6), the combined problem of noise generating unevenness at joints, which becomes a problem when the wearing courses around the joints are silent, and the short life time of bituminous joints (2-3 years on average) was addressed. Several ideas, varying from completely new to applications that worked in other countries, were evaluated. The first step was an evaluation on concept. The best 10 ideas were analysed mechanically through 3D Finite Elements Analysis, which required a number of characteristics to be determined in the laboratory. In each step, the most promising products were selected. After the FEM simulations, four products were tested in Accelerated Pavement Testing using the LINTRACK facility at the Delft University of Technology (TUD) and the three products that performed best in these tests were then used on actual highways. Those products performed well and are now available as standard solutions.

Fig. 6: Long lasting joints project, FEM simulations in smallest (bottom left) and largest (bottom centre) opening, locations in the highway A50 where four products were field tested (right) and construction photo (top)

B. *Innovation Test Center (ITC)*

As explained before, the ITC approach is based on the development of new products or techniques for soil, road or hydraulic engineering that the developer wants to apply in projects for RWS. ITC was started in 2001 and currently results in between 40 and 50 requests for information and contact per year. These contacts result in 10 to 15 actual applications for a validation procedure of which about five are accepted. Rejection can be based on lack of originality, insufficient benefit for RWS or insufficient development. The latter means that ITC focusses on validation of innovations, not on the development. That part is up to the developer, unless there is a specific need in which case a call for innovations as mentioned in section II.A is launched. The validation procedure can be time consuming, the more innovative the idea, the more risks and thus, the more research is needed. About 2 to 3 validations are finished per year and that comes with a decision whether or not the product is acceptable for RWS.

In these validations the costs are shared between RWS and the developer and the latter retains his intellectual property rights. Two examples of successful validations are five products for the protection of (longitudinal) joints (Fig. 7) and a method for low temperature production of mixtures with reclaimed asphalt (greenway LE).

The longitudinal joint protectors were the result of a call for ideas. Typically, the right hand lane of PA wearing courses does not last as long as the other lanes. When this lane is replaced, a cold joint between the lanes is the result. This joint is sensitive to damage (ravelling). To prevent this, bituminous joint protectors are used. Due to traffic they lose their aggregate covering, causing them to be slippery. Also, they cause confusion in dark and wet conditions because they reflect the light, which makes them look like road markings ("ghost markings"). The call was for solutions to this problem. The best five ideas were validated by ITC and have been accepted for application in RWS projects early in 2015.

Fig. 7: One of the 5 innovative joint protectors that was successfully validated

Greenway LE is a a production procedure that allows the production of AC with up to 60% reclaimed asphalt at lower temperatures (ca 105 ^{o}C). The procedure saves about 25% energy relative to hot mix production and also reduces CO_2, NO_x and other emissions, while resulting in a homogenous mixture. This kind of validations usually takes long, because of uncertainties in field performance. The lab phase of the validation was done in 2010-2012, after that the material was accepted for two field trials. These were constructed in 2012, evaluated in 2014 and the product is accepted for RWS application in 2015.

C. Individual validation procedure

RWS contracts specify that only materials that are fit for the purpose for which they are used may be applied in projects. The fitness for use can be demonstrated in two ways, it can either be a standard material, which are specified in the Dutch standard for Soils, Road and Hydraulic engineering [6], or the material has been accepted after successful conclusion of an RWS validation program. The aim of this pre-requisite is twofold, first it prevents unproven innovations from becoming wide spread which could result in an unexpected increase in maintenance costs and second it requires developers to get their innovation approved before offering it in projects. This prevents the additional load of assessing a non-standard material while working within the strict time restraints of a construction project. Up to recently, this part of the innovation validation procedures was relatively under developed, with little standardisation, which made it hard to manage. Currently, it is being streamlined working with blueprints for types of innovations that are fitted to a specific case.

The assessment of the innovation for validation starts with detailed information from the developer. This information should describe the innovation, the standard material for which it is meant to be an alternative and the benefits for RWS. These benefits can be many things, costs (more cost-effective), less traffic hindrance, more noise reduction, more environmentally friendly etc.

On the basis of this information the appropriate blueprint can be determined. These blueprints start from a comparison of the new product to that for which it is meant to be an alternative. The differences between the two define the areas of risk and that is the focus of the validation. In other areas the innovation should meet the requirements to be accepted for use and it must be as good as or better than the product for which it is an alternative in order to offer value for money. That part of the blue print is standard and requires specific tests for which the required and expected values are known. Once also the part covering the unique aspects of the innovation have been identified and tests for the critical aspects are defined, the second part of the validation can start. This is all laboratory based. If the results from this part are not satisfactorily, the innovation is not accepted. If the results are satisfactorily, the third part is initiated, so there is a go/no go decision at the end of part 2 of the validation procedure.

The third part is the construction of a field or semi-field (APT) test section. In case of an actual field test, the developer gets a letter indicating that the first part of the validation is finished and now validation in practice is needed. With that, he can ask the project teams in RWS projects if they are willing to host a test section. The project teams have to discuss this with the road owner and, since these are not major innovations, they do not have to change the warranty conditions. Normally, unless there are specific issues in the project, building such a test section will not be a problem. During construction the production and construction aspects can be assessed. After that, depending on the kind of innovation and the results in this phase, the innovation can be declined, accepted or an indication that a period of more frequent performance monitoring is needed for final validation. If an innovation is accepted, it is also labelled with an expected life time. Typically, this will have to be at least equal to that of the product for which it is an alternative, but in some cases it may differ. Whether or not the product lives up to that expectation will be monitored, since it is crucial in getting a realistic indication of the cost-benefit ratio and other qualities of the product.

Some examples of this kind of innovation are: validation of several PA mixtures with reclaimed asphalt and low temperature AC mixtures for base and binder layers.

III. Current innovation challenges in the Netherlands

A. *Innovation topics*

The main challenges for road engineers in the Netherlands for the coming decade are:

- fundamental performance indicators for field performance
- quick and low-hindrance monitoring and maintenance techniques
- increased noise reduction solutions

The first is necessary to cope with the expected rapid changes in mix composition in providing reliable performance predictions without the time consuming development of empirical relations. Those changes in composition are the result of the decreasing availability of raw materials, which will result in the use of increased amounts of recycled material, repetitive recycling and alternative materials like bio-binders. This is a wide field, which involves the development of alternative mix formulations, advanced recycling techniques and bio binders, as well as fundamental research in to the chemical composition of these and well-known materials in order to establish how chemistry results in mechanical properties and how changes in the chemistry due to aging affect those properties. Due to its wide scope, there is not currently a joined innovation effort on this topic, but there are many companies, research institutes and also RWS sponsored projects into various parts. One of those, a long-term program aiming to use construction projects to assess the predictive quality of the current functional requirements for pavement performance. This program uses the Dutch road network as a living laboratory, hence its name: NL-LAB [7].

Both the second and third theme are related to the high traffic intensities on the Dutch highways. There are many locations in the mid-western part of the Netherlands where the daily traffic intensity is between the 60.000 and 100.000 vehicles per day (Fig. 9 and [8]), which adds up to one car every 1,4 to 0,9 seconds. This is only expected to increase in the next decade. As a result there is less and less time available for performance monitoring and maintenance, while the aging of the infrastructure makes continuous monitoring more important than ever. As a result, there is an increasing demand for non-invasive, rapid and/or low hindrance monitoring and maintenance tools. As a result, several projects along these lines are currently ongoing within the RWS innovation portfolio.

For monitoring, for example, RWS is working on the development of laser measuring systems for ravelling and cracking, including automated interpretation algorithms. This so-called LCMS (Laser Cracking Measuring System) is developed in cooperation between RWS and TNO (Fig. 8 and [9]).

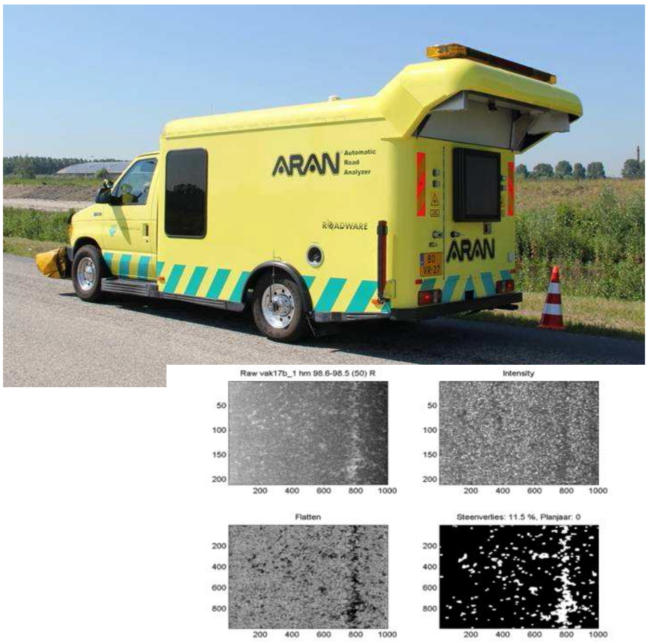


Fig. 8: LCMS laser measuring unit integrated with the ARAN (top) and the resulting measurement and translation into stone loss (bottom)

Projects focussing on rapid and/or low hindrance maintenance includes PA with steel fibres, where induction is used to heat the steel fibres when damage due to cracking is initiated. The heating of the fibres melts the bitumen and will allow rapid and durable healing of micro damage [10]. Naturally, the fibres have to be incorporated in the mixtures when constructing the pavement. So, if this solutions proves viable, it will be useful for newly constructed pavements.

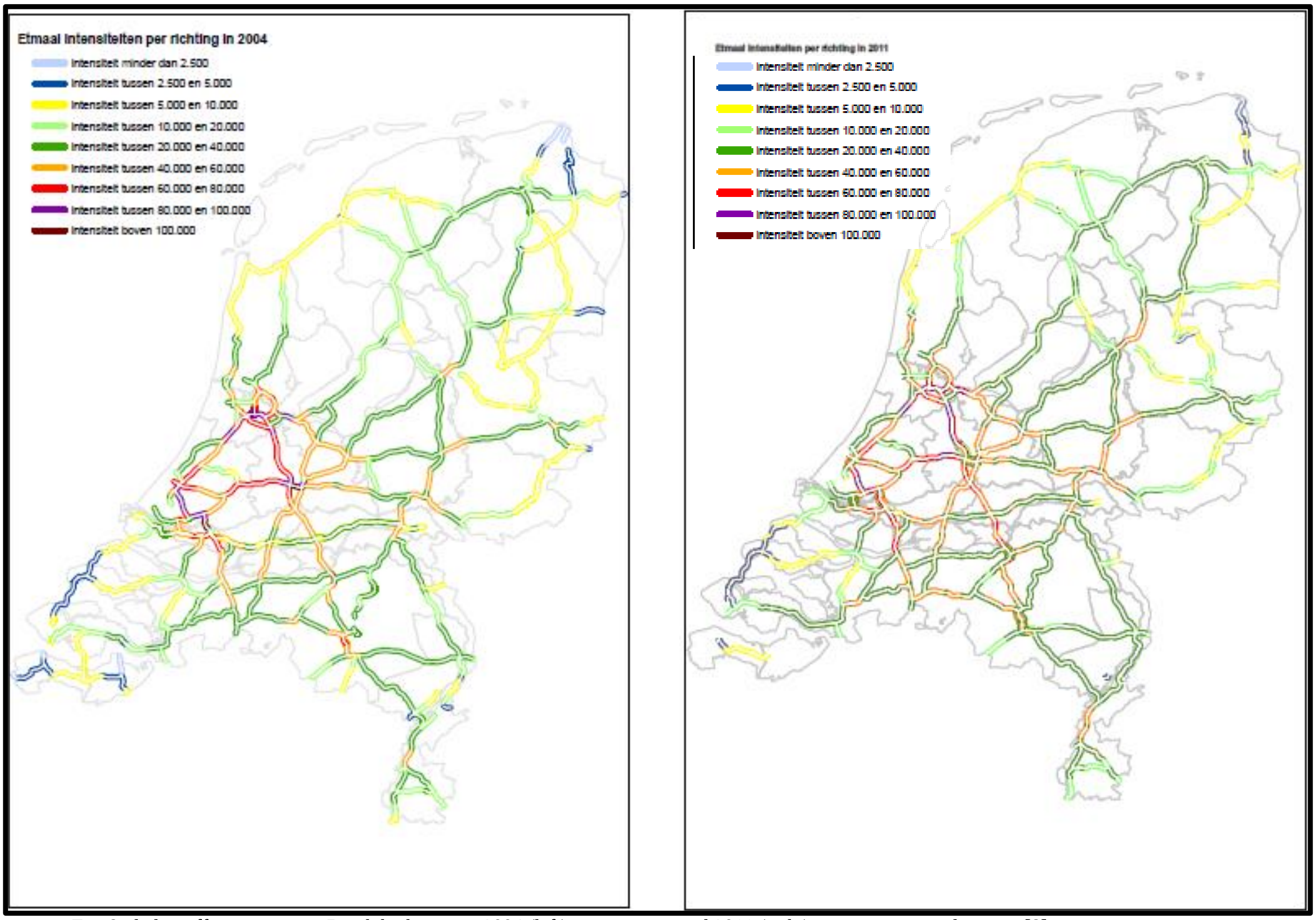
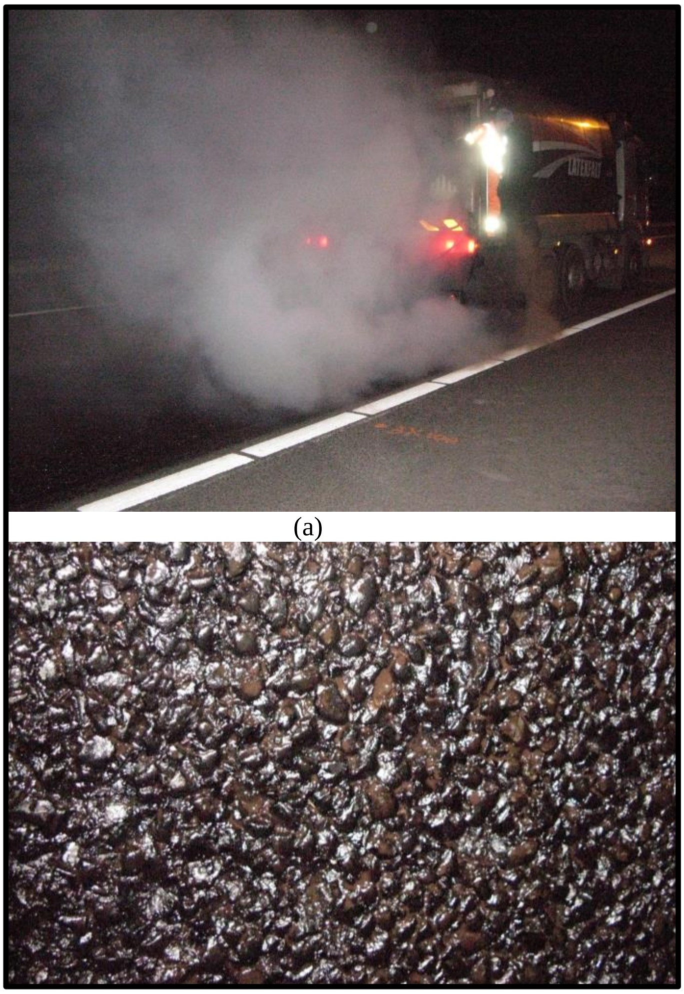


Fig. 9: daily traffic intensity on Dutch highways in 2004 (left) and 2011 (right), intensity in one direction [8]

Another ongoing project focusing on rapid maintenance is rejuvenation, which involves products that aim to replenish volatiles that disappear from the bitumen due to aging. If used in-situ, rejuvenators also heal (micro) cracking by replenishing the bitumen that eroded over time. Rejuvenators that are included in bitumen emulsions are studied as a maintenance measure for in-situ PA wearing courses, a rapid, life time extending technique which is meant to increase the life time of the right hand lane to such an extent that all lanes can be replaced in one major maintenance round once the left hand lanes reach the end of their service life. The rejuvenating component itself is also studied for use in recycling of AC in plants in order to increase to amount of reclaimed asphalt that can be used and to allow for repeated, even infinite, recycling.

There is no final agreement on how the rejuvenators work and whether the replenishing of volatiles really occurs, restoring both stiffness and strength [11]. However, the field evaluation that is carried out in parallel to the scientific investigations, indicates that rejuvenators do increase the life time of the pavement. The scientific evaluation remains important, because when it is known how this work, optimization is possible and it is also clear when it will not work. For the Dutch condition, it is especially useful if rejuvenators can be used to postpone maintenance of the right hand, heavy trafficked lane until the other lanes also need replacement. Currently, the life time extension is not on that level, but it does provide a useful maintenance tool to extend the life time of weak spots in a pavement.

Finally, in order to try and establish further noise reduction through wearing courses in order to prevent expensive noise barriers even when the traffic intensity and population density increase further, the RWS innovation program is funding research into Poro Elastic Road Surfaces (PERS). These wearing courses should ideally result in 10 dB noise reduction (relative to DAC), be cost-effective and have a service life of at least 7 years. There are 3 consortia involved in developing products that are tested within the program. Currently, the laboratory work is underway and in the next stage APT testing will be carried out. Eventually, if the materials appear satisfactorily, they will be further validated in test sections.



(a)

(b)

Fig. 10: Application of rejunvenator (a, top) and the PA surface after application (b, bottom)

B. Challenges in innovation procedures

The three tier approach to innovation will need to be integrated more fully, to ensure that developers know where they can go in which situation. RWS working on this, trying to establish a central point for ideas and queries which will either forward an idea to the appropriate validation procedure or will result in a quick explanation of why the idea will not be validated.

With the changing responsibilities in the sector and the reduction of personnel at RWS it seems unlikely that all innovations submitted for validation, especially in the final tier, can be accommodated. To limit the capacity the validations require, a filtering mechanism will have to be implemented. It is unclear what form this will take, it could be a waiting list, with starting a new validation only once another is finished. Or it can involve some kind of call-system where ideas can be submitted before a certain date, after which the benefits for RWS are assessed and only the first so many most beneficial ideas are accepted for validation. Alternatively, an independent organisation could be used to assess the innovations, either payed for by RWS, the developer of the innovation or a combination of both. In case the solution is found in limiting the innovations that are accepted for validation, developers will face a bottleneck in getting new product or procedures accepted and may want to establish an independent organisation for the validation of innovations, anyway.

Another aspect of the innovation procedures that requires improvement is the product identification. Up until recently, including several of the ongoing projects, the products were considered autonomous systems and treated as black boxes, without any detailed identification. As a result, checking a product after the validation is only possible indirectly, through its performance. Due to a lack of well-established performance related specifications, especially of course for innovations, this is attractive in theory but not feasible in practice. To allow for product testing, therefor, detailed product descriptions based on the constituent materials and there proportions should become an integral part of the validation.

Finally, the third type of validation is currently completely carried out by the developer. In order to further improve objectivity and quality, random checks by independent research facilities need to be incorporated in the system.

IV. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Rapid changes in our surroundings necessitate innovations in road engineering. In the Netherlands Rijkswaterstaat uses a three tier approach to the initiation and validation of innovations. They deal with solicited validations to solve a challenge as well as unsolicited innovations with potential benefits for RWS. Topics dealt with in innovations cover materials (mostly) but also maintenance and monitoring techniques, several examples are presented in this paper.

Although there is considerable experience with the three levels of validation, the system is still being improved. And further evaluations and development of the system is recommended to be able to continue to address the challenges faced in road engineering.

The specific challenges countries are facing, will be different depending on their climate, location with respect to oceans, social and economic situation. But due to the world wide trends, all countries face rapid changes that have to be addressed to ensure the continued functioning of their road network. For that reason, all countries will need to find a way to encourage and assess innovations. The Dutch system will not work for all countries, but the ideas and experiences described in this paper may provide inspiration or lead to an exchange of approaches and experiences that will benefit everyone.

Similarly, the innovations discussed won't be useful in all situations and all countries. The innovation that has the most potential worldwide are the rejuvenators. Every type of wearing course that uses bitumen, whether it is a dense type of asphalt concrete, a porous one or a chip seal can be treated with rejuvenators. And experience with the materials in various situations will enable a better understanding of how and why it works, which will eventually lead to a reference frame for the optimal use.

Although local circumstances can vary considerably, many of the underlying challenges are the same. For that reason, the exchange of research and innovation practises and experiences like those obtained from the FHWA Exploratory Advanced Research Program, can provide worthwhile information and ideas for contractors, developers, research institutes and road authorities all over the world. This paper aims to contribute to that exchange by providing an overview of the Dutch approach towards innovation validation as well as some examples of past and ongoing validation projects.

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