# ROAD SURFACE OF THE FUTURE

A.C. Maagdenberg & N.M.M. Koeleman
Road and Hydraulic Engineering Department, Directorate General Rijkswaterstaat,
Ministry of Transport, Public Works and Water management
The Netherlands
A.C.Maagdenberg@dww.rws.minvenw.nl

## ABSTRACT

In 1996 the Ministry of Public Works and Water management started the innovation programme 'Roads to the Future' to anticipate on the future needs in mobility. In 2000 the theme 'Road Surface of the Future' began its search for a completely different approach to infrastructure, its functions and its components. At the heart of this new approach lies the world view in 2030: increased mobility, more shortages, far-reaching technological development and explicitly more integral designs. What are the potential functions of the road in this view? Are current solutions still suitable or do we need a trend-change in design, construction, composition and use of infrastructure.

As the result of a gradual process the traditional method of constructing a road surface has an amorphous mixture of qualities that must fulfil an entire scale of functions. Over the past decades, the hot-rolled asphalt superstructure evolved from providing a comfort layer to being a bearing construction, comfort layer, water drainage layer and noise reducing layer all in one. The functional requirements will vary according to place and time. By unravelling the functions and developing specific components or modules for each function a ' made-to-measure' road surface can be created by stacking the right layers on top of each other, provided that it should be easy to exchange the modules.

In 2001 the ideas for a Road Surfce of the Future were elaborated in three practical pilot projects: Modular Road, Smart Road and Energetic Road to demonstrate that this new concept of construction could be feasible. The paper describes these pilot projects and the very promising results obtained.

## KEY WORDS

INNOVATION / PAVEMENT / PRE-FAB / NOISE / SMART / ENERGY

## 1. BACKGROUND

Road transportation and specially its physical component, i.e. road infrastructure, play a prominent role in the social and economical life. A world without infrastructure or the possibility to transport goods and people is unimaginable and would represent a deterioration in the progress of both economic and social development. The potential now offered to broaden horizons has changed the nature of society. In spite of the range of technical solutions available to enhance level of comfort, society has become increasingly critical and demanding as far as the environmental impact due to infrastructure is concerned. For instance, road use is a universal amenity, yet no one actually wants to see a road, hear the traffic and smell the exhaust or lose precious time in traffic jams. Road infrastructure demands have evolved heavily over the past decade: people still require infrastructure but not at any cost.

The last decades are marked by a tremendous growth in vehicle traffic and an increasing discrepancy between infrastructure capacity, supply and demand. This is especially true for road transport and will probably remain so for many years to come, even if intermodality develops to a large extent. All parties concerned agree that laying more square meters of asphalt by building new roads and widening existing roads cannot alone solve traffic congestion problems. Smart solutions capable of making better use of the existing infrastructure must also be developed to keep the traffic flowing.

In general the current policy concerning ground transportation is a reaction on developments already settled down. For instance the legalization of hands free calling in cars started the moment that almost every driver uses his mobile phone whilst driving and the first accidents with severe injuries had already occurred. When traffic blocks completely during rush hours a first wary thought about possible solutions starts. Generally the solutions proposed will be based on the state of the art of the current technical options with sometimes a restyling of well-known construction methods and materials. However the running time of an infrastructure project from drawing-table till full-scale implementation takes ten years or more. It is not out of the question that the proposed solutions of to day are already outdated when implemented in practice and will not fit the problems of tomorrow.

A better understanding of the consequences of ongoing developments and a better anticipation on trends is necessary to prevent wrong investments. To be ready for facing the problems of tomorrow it is essential to get a picture of the future: a vision of the functions and the use of the road infrastructure in the future. What are the future needs and demands concerning road transportation, given social developments like for instance an increasing need of transfers of goods and people on the one side, and increasing individual demands and an increasingly ageing population on the other side. A vision of the future offers us an out-line of the issues and technological developments needed to face the future with confidence. Working backwards from a vision of the future is an essential phase for establishing breakthroughs in new road building and maintenance concepts as well as in technological innovations. Looking ahead over a period of thirty to forty years and forecasting the future needs and demands offers policymakers the technical means for proactive progress instead of reactive progress.

In 1996 the Ministry of Public Works and Water management started the innovation program 'Roads to the Future' (RttF) to anticipate on the future needs in mobility. This program is characterised by pilot projects with short-term steps and a long-term perspective. RttF's dynamical character is reflected in the objective of completing the pilot projects within two years. So the program combines long-term thinking with short-term actions.

## 2. LONG-TERM THINKING

Innovation without a cogent view of the implementation setting makes little sense. In this case, innovative ideas would lie bare and would be unable to withstand the surrounding chaos. Innovations must serve a purpose and lend direction to new developments.

In this context the theme 'Road Surface of the Future' of the innovation program 'Roads to the future', started in 2000. The aim of this theme was to open doors to a completely different approach to infrastructure, its functions and components. Drastic improvements, perhaps an entirely different view of what we want or can do with infrastructure, were not excluded. At the heart of this new approach stood the world view in 2030: increasing need of transfers of goods and people, scarcity of infrastructure capacity, liveable environment, energy and space, far-reaching technological developments, stronger market influences, and explicitly more integral designs.

A broad debate was held with members of society and professionals of industry and related disciplines to establish the impact of this world view 2030 on the functions of the road and the needs and demands of road infrastructure. According to the opinion of this discussion group the road in 2030 will be:

- *Multifunctional*, emphasising the combination of transport-oriented or non-transport-oriented activities, including functional integration.
- *Low in energy consumption and low in emission*, emphasising the self-providing road where pollution becomes raw material and climate and traffic movement are converted into fuel. An invitation to the need of an environment without impediments in 2030.
- *Smart*, a road that guides reacts and thinks along with the road user. A concept making the current static road body into an organic, dynamic object and thus optimising the transport function of the road.
- *Nice*, emphasising the road as agreeable scenery and shelter for the road user.

As the result of a gradual process the traditional method of constructing a road surface has an amorphous mixture of qualities that must fulfil an entire gamut of functions. Over the past decades, the hot-rolled asphalt superstructure evolved from providing a comfort layer to being a bearing construction, comfort layer, water drainage layer and noise reducing layer in one. The functional requirements will vary according to place and time. Adding the package of potential functions of the road in 2030 demands a change in the trend of design, composition and construction of infrastructure: a 'made to measure' road that can meet a variety of functional requirements according to place and time. Made-to-measure, in that a quiet road is more desirable at certain times and places than at others. Because heavy lorry traffic has other requirements/wishes in terms of comfort and carrying capacity. And because the nature and scope vary the intelligence of the road surface (including detection) must also be made-to-measure, as must the manner in which the road is to be used for winning renewable energy.

By unravelling the functions and developing specific components or modules for each function a ' made-to-measure' road surface can be created by stacking the right layers on top of each other, provided that it should be easy to exchange the modules. This new approach provides the conditions for a far-reaching industrialisation of road surfaces, thus also providing a wide range of options for innovation. The modular concept of construction offers possibilities for separate development and building of all sorts of smart and efficient elements, such as dynamic lane marking, sensors, induction loops and energy-generating elements. Off-site prefabrication of elements under controlled circumstances also leads to a higher quality of the products. Assembling the components on site minimises the time needed for construction and maintenance, thus reducing traffic hindrance.

## 3. SHORT-TERM ACTIONS

In order to outline the first step in the scenario above the theme Road Surface of the Future has challenged the market to submit ideas for three pilot projects:

- *Modular Road, the 'prefab future road surface'*: road surface that can be adapted to the local and current conditions, constructed with prefabricated parts that can easily be rolled up and off, also providing a noise reduction function. This is the first reconnaissance of the new frame for the construction of the road surface.
- *Smart Road, 'Zipping Up with Electronic Guides'*: a road surface that observes, interprets, decides and acts, thus trying to influence the road user's behaviour in order to help him or her to travel safely and comfortably in traffic. The demonstration provides support to the individual road users in the process of zipping up. This pilot projects main aim is the function of intelligent support of traffic.

- *Energetic Road*: real-size execution on/in/beside and along roads of an efficient mix of forms of durable energy production, which eventually should lead to the (partial) provision of energy needs of road and traffic. On the long term, it is likely to be paying its way, also meeting the conditions with regard to traffic safety. This pilot focuses on the function of energy production.

## 4. MODULAR ROAD

The pilot project Modular Road Surfaces has been set up to demonstrate that this new concept of construction can be feasible. The market has been challenged to design an actual road surface layer, preferably prefab, that is easy to apply (and to drive on) and easy to remove (100 m per hour right across the roadway) in any case. An additional challenge is the large step hat has to be taken in terms of noise reduction: over 5dB(A) more noise reduction than dense asphalt concrete. From the twenty ideas submitted only the following four ideas were worked out in a design and were demonstrated along the motorway A50 near Apeldoorn.

3.1. The Very Silent Noise Module
This concept (figure 1), submitted by a consortium headed by Koninklijke Wegenbouw Stevin, consists of a supporting layer of elongated concrete elements, laid diagonally to the driving direction, and the functional modules, laid staggered on the supporting layer. Cement concrete or the new composite material C-Fix (carbon fixation) is used to construct the supporting layer. This C-fix binder is made from residual oil refinery products and has a very high carbon content. The production of the material has the advantage of a low $CO_2$ emission into the atmosphere. Ridges and the weight of the modules guarantee

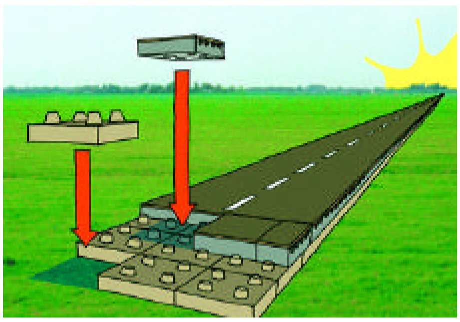


Figure 1. The very Silent Noise Module

that the two layers remain fixed horizontally; the flat surfaces of the layer and not the ridges lie ontop of each other. The concrete part of the functional modules contains Helmholz resonators on top. These cavities absorb specific noise and energy frequencies so that they disappear from the original sound wave. The surface layer of these modules is formed by a thin uni-layer of very silent porous asphalt (ZSA). Measurements and additional calculations indicate a noise reduction of 13$\pm$4 dB(A) is feasible by this combination of ZSA and Helmholz resonators.

3.2. The Rollable Road
A consortium headed by Heijmans Infrastructure & Milieu has developed this three-layer design (figure 2). The top two layers with a total thickness of 30 mm form the surface layer that is prefabricated as a single, rollable layer. The arc of the roll is about 1 metre. Each layer consists of a flexibly bonded mineral mix (graded 3-6-mm) with a certain degree of porosity. By fabricating the layer up side down the road surface is free of irregularities in

the macro-texture so that the car tyres vibrate minimally. The supporting layer consists of high bearing capacity concrete-slab elements with Helmholz resonators on top. Besides

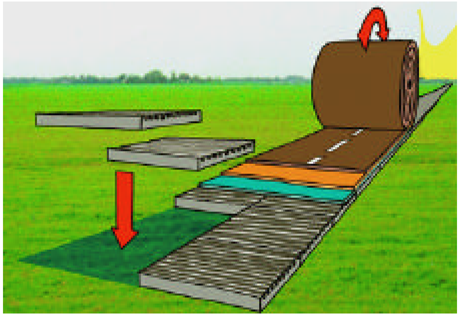


Figure 2. The Rollable Road

absorbing noise frequencies, these cavities discharge the rainwater. After the supporting elements were laid on an existing or new road subgrade the top layer can be rolled out. The rollable layer is fixed to the supporting elements with a bituminous bonding layer. The assembling is free of weather-sensitive actions so a high work pace can be achieved both for laying and replacing the elements. Calculations, based on laboratory measurements, indicate that the entire package results in a road surface with a noise-reducing capacity of around 10 dB(A).

3.3. ModieSlab

Modieslab, submitted by ModieSlab Ltd, was designed as an extremely durable concept, resulting in a settlement-free road (figure 3). The relatively high construction costs are set-off by an estimated life-cycle of 25 years, which means that the costs of maintenance and costs for society as a result of traffic nuisance will be very limited.

ModieSlab consists of prefab concrete slab elements that cover the full width of the road (12 meters). The standard width of the elements (the distance in the driving direction) is 3.5 meters. These dimensions make transport by standard means of transport possible. A so-called double-layered porous concrete forms the road surface of the elements:

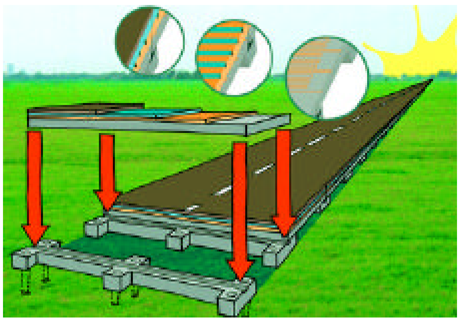


Figure 3. ModieSlab

15 mm porous concrete with fine aggregates upon 35-55 mm porous concrete with coarse crushed aggregates. This results in a noise-reduction of 7 dB(A). Under the two top layers are detection wires and pipes for discharging the rainwater. A reinforced concrete slab of approximately 35 cm thickness supports the top layers. These slabs contain a pipeline register for regulating the temperature and so the dilatation. In winter this keeps the road surface frost-free. The temperature regulation pipeline is connected to two aquifer sources via heat exchangers. The slabs are placed upon prefabricated concrete ties and supporting beams. If the ground or embankment is not settlement free, pile foundations

can be used to support the beams. After the modules are put into position from a special carrier the line supports are adjusted in height and set where necessary. Re-adjusting is rarely necessary but always possible.

### 3.4. The Adhesive Road

The concept of the 'Adhesive Road', developed by Vermeer Infrastructure, has an innovative switch on/off system to fix and remove a prefabricated, rollable asphalt layer on an existing road surface (figure 4). The rollable asphalt layer is constructed upon a specially designed geosyntatic fabric supporting layer that also acts as an adhesive layer. This (flat) carrier and the specially designed flexible bonding agent in the asphalt mix enable the entire asphalt mat to be rolled up easily, without damaging it. The asphalt mat is made on a conveyor belt and, after cooling, rolled onto a reel (with an inside diameter of 1.5 m), sealed, and put away in storage. On demand, it is transported to the construction site where it is rolled off of a reel wagon. Prefabrication guarantees a consistent, high-quality end product and offers the opportunity of producing different variants of the product according to the performance requirements (noise reduction, life-cycle, skid resistance, etc.). The length, width and thickness are variable. The standard dimensions are 50 m by 3.6 m. The prefab production process also enables geometric made-to-measure production of a road surface. After measuring the road, any random form can be produced, as well as any arc. An asphalt mixture with an open structure was developed for this pilot project. By using a 30-mm layer, a noise reduction exceeding 5 dB(A) can be achieved.

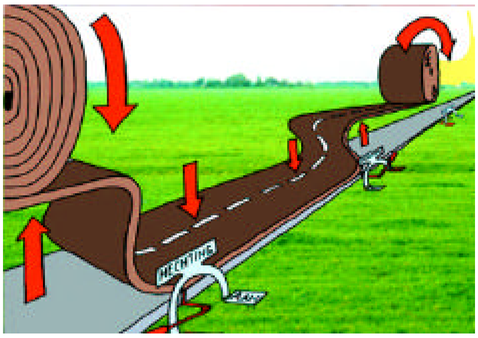



Figure 4. The Adhesive Road

By means of electromagnetic waves or induction this adhesive layer is activated. After rolling out the asphalt layer over the existing road surface one passage of the microwave equipment and a roller the road surface is immediately ready to be driven on. Using the same equipment, the adhesion between the 'old' and 'new' road surface can be 'switched off'. Replacement speed is approx. 300 m of road surface per hour. The removed asphalt mat is rolled up and taken to the plant to be upgraded.

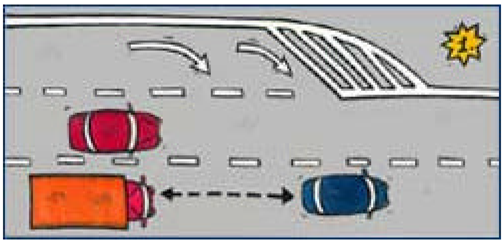
The 'Adhesive Road' was initially designed for use as a road surface on motorways. But the many advantages and degree of freedom that this concept offers imply that it may well be suitable for other applications, such as in urban areas, bridge decks and parking roofs.

## 5. SMART ROAD

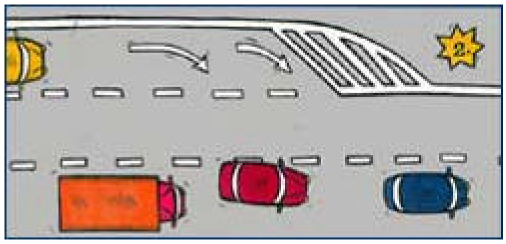
A smart road observes, interprets, decides and acts, thus trying to influence the road user's behaviour in order to help him or her to travel safely and comfortably in traffic. In this context a lot of potential applications are imaginable. Because the pilot will be a demonstration under real traffic circumstances and because of the absence of practical experience with smart road concepts it was necessary that the safety of the road users prevails the ambition: low risk profile, but a high safety level. As a first step in the development of a smart road surface (a road that actively regulates the traffic using it) a pilot has been chosen that supports the merging process at a location where a 3-lane road changes into two lanes. For the time being, the support of this pilot ‘Zipping up with electronic guides’ has to take place with only auxiliary signalling and without intervening in control systems in the vehicles. The road user himself decides whether or not he will do something with the ‘zip support’ information and whether he will adjust his driving. Object of this pilot project is the closer examination of the possibility to influence the behaviour of the road user during zipping up. The pilot must accompany the zipper comfortably and safely along the zip area by means of appropriate signalling, which renders the zipping easier and smoother.

In order to take a closer look at the interaction between road user and specific zipping signalling, ‘driving simulation tests’ on random selected road users in a ‘laboratory environment’ have to be conducted prior to the practical test. Here it will be possible to study the aspects of acceptance, behaviour and sensory physiology of the zipping system, so that a practical and safe pilot implementation may be achieved.

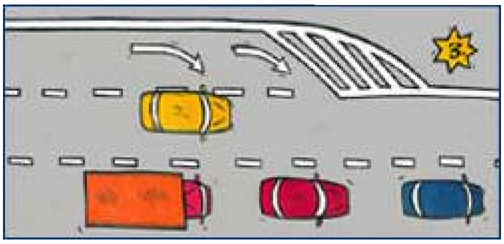
The ‘zipping up’ competition started with six entries out of which two were selected for working out the concept and simulation testing. The ‘Denkdek (thinking road)’ concept, developed by Koninklijke BAM Group, passed these tests successfully. The principle of this concept is shown in figure 5.



Step 1



Step 2



Step 3

Figure 5. Principle of ‘Denkdek’

Along a motorway near Amsterdam, a test is done with the ‘Denkdek’. This concept uses technology of dynamic road marking at a location where a 3-lane road changes into 2 lanes. Just before the test area several preparatory measures are taken. Truck drivers are concentrated into the right-hand lane by prohibiting overtaking, thus creating a calm traffic situation. Indicating various speed limits using electronic signs above the lanes to further influences traffic behaviour. A public information sign in the verge then indicates that the driver must follow the moving striped light line along the hard shoulder. This light line runs at the desired speed of the driver, thus creating gaps between vehicles. (step 1). At the test site, an arrow to the right encourages the drives in the middle lane to merge into the right-hand lane. (step 2). Vehicles filtering into the right-hand lane create room in the middle lane for drivers to merge from the left-hand lane (step 3). This is also encouraged by an arrow to the right on the electronic traffic information sign above the left-hand lane.

## 6. ENERGETIC ROAD

The worldview 2030 assumes that motorway systems will increasingly provide for their energy needs. They will become closed systems with low energy inputs and low emissions, which will benefit the environment. Ground transportation will make much more use of renewable energy but at the same time the energy demand will rise because of an increase of facilities on motorways, such as traffic control systems, intelligent road markings and various communication systems.

Energy recovery from infrastructure is a live issue. The topic supports the political objective of meeting 10% of all energy needs from renewable sources by the year 2010. And the motorway system does, after all, have an enormous surface potential, which, given its volume, is particularly attractive to low-yield energy-generating techniques. By using mutually reinforcing and supplementary sustainable sources (heat from the sun, cold from the air, cold & heat from the ground, wind) and technologies to convert the energy from these sources virtually a constant availability of (electrical) energy would be achieved. Whilst the space they took up and their spread-out appearance made first generation motorways target of community protests, this problem of scale can be turned into an advantage by presenting the second generation motorway as a giant energy-generating system.

Key goal of the Energetic Road pilot is to recover as much renewable energy as possible from a kilometre of motorway. The pilot also has the aim to stimulate the scientists all over the world to pay more attention to the huge potential possibilities of infrastructure for generating renewable energy. From the fourteen ideas submitted, the EC-fics concept of Koninklijke BAM Group was selected, because of its high innovation standard and challenged character. The heart of EC-fics is the Thermoroad concept: prefabricated elements consisting of thermocouples and a network of pipes connected to underground heat/cold storages. These elements are built-in into the pavement construction (figure 6). As the sun heats the asphalt, a temperature gradient is created across the thermocouples, causing them to generate electricity. The elements are placed in an insulting course to prevent electrical or thermal short-circuiting between elements. The network of pipes

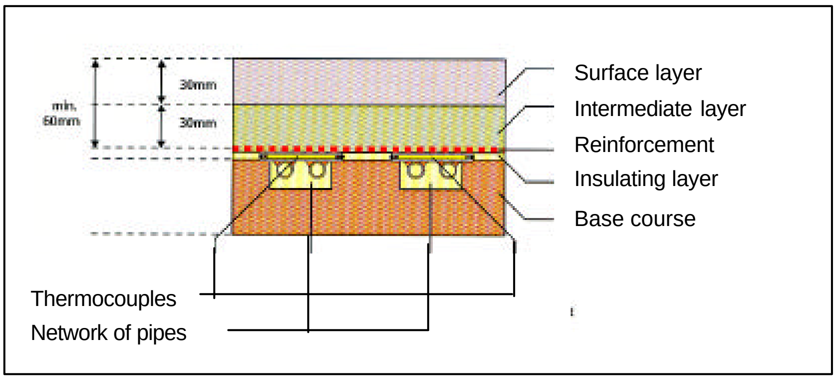



Figure 6. EC-fics Thermoroad

placed underneath the thermocouples allows influencing the temperature gradient. A cold (summer) or warm (winter) medium flows through the pipes. By applying Shell's C-fix, a new carbon rich binder, in the intermediate course it is possible to optimise further the conduction of heat from the road surface.

In addition to Thermoroad, EC-fics also includes a new type of wind turbine: the vertical wind turbine. This wind turbine allows making use of wind in a safe manner. Its shape means that the vertical wind turbine does not constitute a distraction, this in contrast to the revolving vanes of traditional wind turbines. As a supplement to the thermocouples, the wind turbines ensure that EC-fics can be operational all year round.

In 2002 a trial section of road using EC-fics has been built on the A50 motorway. After installing an extensive monitoring system, the trial has started this summer to investigate if and how EC-fics will function in practice. Besides a development stage will start to optimise the various elements of Thermoroad, not just with regard to the properties of materials and energy yield, but certainly also with regard to cost.

## 7. FOLLOW UP

The selected pilot ideas were elaborated into realistic designs within a period of 6 month from the starting point of the competition. These designs as well as the ideas, submitted but not selected, were processed in confidentiality. The proprietary rights of ideas and detailed designs belong to the consortiums participating in the competition. The Ministry of Transport and Public Works only claims the user rights including the application of the selected designs in professional practice. To build the pilots the pilot teams, affected with a high standard of improvisation and creativity, had to turn back to the existing organisation, struggling with strict regulations concerning the execution of constructional works. Type of licences needed and the enthusiasm of the people involved determine the passing through of the building phase.

The four designs of the pilot project Modular Road Surface were delivered in December 2001. At the same time a monitoring program of one year started. Besides the pavements were constructed on the site of the Lintrac traffic load simulator, an accelerated loading test, to investigate the long-term performance. The Smart Road pilot 'Zipping up with electronic guides' was delivered in April 2003. In August a monitoring program under real traffic conditions started for a period of at least three month. The construction of the Thermoroad, part of the pilot Energetic Road, including an extensive monitoring system was finished in August 2003. This concept also will be monitored over a period of one year.

## REFERENCES

Wesseling, J. W. (2003) How to Foster Innovation in a large Governmental Organization?. XXII PIARC World Road Congress, session 'Innovations in Infrastructure Design and Utilization'.