Conférence Européenne des Directeurs des Routes

Conference of European Directors of Roads

CEDR TRANSNATIONAL ROAD RESEARCH PROGRAMME

Call 2017

New Materials & Techniques

CEDR Transnational Road Research Programme

funded by

Austria, Belgium-Flanders, Denmark, Germany, Netherlands, Norway, Slovenia, Sweden and the United Kingdom

Description of Research Needs (DoRN)

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1 General introduction

This Call for Proposals is launched by the Conference of European Directors of Roads (CEDR). CEDR is an organisation which brings together the directors of 27 European road authorities. The aim of CEDR is to promote excellence in the management of roads. The website www.cedr.eu contains a full description of its structure and activities.

CEDR recognises the importance of research in the development of sustainable transport and has established a Working Group (WG) to monitor European research activities and to advise the CEDR Governing Board (GB) on issues relating to research. WG Innovation (WGI) responsibilities include dissemination of research results as well as initiating research programmes that support CEDR members in current and future situations.

CEDR gave a mandate to its Working Group Innovation (WGI) to identify opportunities for further transnational road research programmes on the basis of the excellent start and of the experience gained during the ERA-NET ROAD project. CEDR also requested that:

- WGI proposes suitable research topics and identifies good research proposals;
- WGI presents research proposals, when appropriate, to the CEDR GB for decision; the CEDR GB will decide what programmes are taken forward;
- all call procedures shall be open and transparent and all European countries shall be invited to participate, with no advantages given to preferred suppliers or groups of suppliers; and
- the costs of developing and managing the transnational calls shall be supported only by those CEDR members taking part in the programme.

2 Introduction to Call 2017

The CEDR Transnational Research Programme was developed initially within the framework of ENR and was then taken forward by WG Innovation to fulfil the common interests of the National Road Administration (NRA) members of CEDR.

The participating NRAs in this Call are Austria, Belgium-Flanders, Denmark, Germany, Netherlands, Norway, Slovenia, Sweden and the United Kingdom. As in previous collaborative research programmes, the participating members will establish a Programme Executive Board (PEB) made up of experts in the topics to be covered. The Common Obligation Programme Model from the "ENR-toolkit" has been adopted, with some modifications to take account of the role of WG Innovation in the process. The research budget will be jointly provided by the NRAs who provide participants to the PEB as listed above. PEB members will designate one of them to act as chair.

WG Innovation has, on behalf of CEDR, appointed a Programme Manager (ProgM) to take over the administration of this Call for Proposals. For this programme, the ProgM will be the Austrian Research Promotion Agency. Responsibilities of the ProgM include preparation of the Call for Proposals, financial management of the programme and setting up and managing the contracts with the research providers. These responsibilities will be conducted by the ProgM in its country under its law and regulations under the direction of WG Innovation. The terms under which the ProgM and PEB will operate will be set out in a Collaboration Agreement, signed by senior representatives of each participating NRA.

Applications are invited from suitable qualified consortia in response to this Call for Proposals. Consortia must consist of at least two legal entities from different European countries. Individuals and organisations involved in the formulation of the Call specification are prohibited from any involvement in proposals. Applications should focus on the sharing of national research, knowledge and experience at all levels as an important prerequisite for achieving the goals of CEDR and its members. It is particularly important that the results can be easily implemented through various demonstration projects in order to contextualise **the benefits of the transnational collaboration.** The applications will be evaluated by the PEB in relation to:

- Extent to which the proposal meets the requirement of the DoRN
- Technical quality of proposal
- Track record of consortium members
- Management of project
- Value for money
- Vision on the topic.

Details of these evaluation criteria and how they will be interpreted and applied by the PEB are presented in the Guide for Applicants (GfA), which accompanies this Call for Proposals.

3 Aim of the Call

The overall aim of the Transnational Research Programme **"New Materials & Techniques"** is to develop concepts and strategies and to demonstrate their applicability to increase the long-term durability of pavements while at the same time ensuring a reduced dependency of raw materials and a low fossil energy demand. The solutions must be **feasible, proven and cost-effective.**

The aim of CEDR Call 2017 is to meet the scope of the CEDR Action Plan according to its strategic goals of facilitating and optimising the efficient use of resources as well as to help finding efficient alternative solutions to optimize pavement durability and to reduce the impact on the environment of petroleum-based materials. A further aim is to make best use of the existing infrastructure by improving sustainability and reducing the environmental impact and carbon footprint. In this context, aspects of recycling and re-use should be taken into account at the design phase of any construction process. Thus, the CEDR Action Plan according to its strategic goals of facilitating and optimising the efficient use of resources will be met.

In recent years a number of CEDR and other projects gained a lot of knowledge on the topics described above. However, most of the achieved results have so far not been implemented and put into practice. The current CEDR Call therefore aims to ease and foster the implementation of the research results on materials and techniques for being applied by the NRAs, i. e. to bridge the step from TRL 7 to the practical implementation of the results by the single NRAs (TRL 8-9). It is aimed that the results from this Call can directly be transformed into practice and into national regulatory frameworks. The participating NRAs will support this by the provision of test areas (demonstrators) that allow the investigation of for example the application procedures for green and recycled materials and prove practical use of variables. The duration of the Call is too short to prove their long-term performance. For that, real time 'in-service' situations can and should be used. After the Call, long-term monitoring of the demonstrators in the test areas will be handled by the NRAs themselves.

The Call has three sub-themes:

- **A: Reliable life cycle and social cost-benefit analysis of "green asphalt"**
- **B: Simplifying the use of RAP**
- **C: Usability of Super Materials**

Applicants should ensure that their project proposals are clearly linked to one of the three objectives listed above. Proposals should emphasise the trans-national benefit of the project outcomes for the participating Road Authorities in the context of getting the most out of Intelligent Infrastructure. These will be high level, generic benefits and it is up to the road authorities to take the results from TRL 7 and to apply the innovation to their own network to exploit those benefits.

4 Reasons for the Transnational Research Programme

The National Road Agency's (NRAs) have to provide a road network with sufficient capacity for transportation of both persons and freight in a cost effective manner. As in most countries road networks are almost complete, today durability and cost effective maintenance are major concerns of all NRAs. It is anticipated that if no action is taken, the durability of pavements will be lowered over the next years due to an increased loading (growth of freight kilometres), climate change (e. g. increased precipitation in short time periods, more freeze thaw cycles, higher temperatures) and a change in origin of construction materials (a shift from primary materials to secondary materials including bio-based materials).

The asphalt materials of the near future will contain a higher share of RA (reclaimed asphalt), be produced at lower temperatures (semi-warm or cold methods) and may have more additives to improve both sustainability and durability. One of the major concerns is that these materials will not fit within the efficiency limits of the NRAs. Therefore, it is compulsory to find an optimal balance between economic sources and societal demands.

In recent years, progress has been made in both the field of materials and for decision models like SCBA (social cost benefit analysis) and LCCA (life cycle cost analysis). However, the required implementation rate of sustainable materials remains rather slow. This is partly due to a lack of demonstration of both the potential benefits of the materials, the way in which they can be used practically and also due to unclear business objectives of the NRAs themselves. Therefore it is necessary to provide precise and practical tools for the NRAs (e. g. appropriate test methods and pavement models). The project results validated in the laboratory and demonstrated in relevant environment (TRL 5 - 6) need to be demonstrated on test sites (TRL 7) to bridge the gap that often exists between theory and practice. This will ease and speed up the transfer of the research results for the practical application by the single NRAs.

5 Research Objectives

The Call for Proposals has the objectives and expected outputs as presented on the following pages.

5.1 Topic A: Reliable life cycle and social cost-benefit analysis of "green asphalt"

5.1.1 Description

The aim of this subtopic is to support CEDR NRAs in their decision to use "green asphalt" to meet their needs on reducing global warming (the Paris Agreement) and improving resource efficiency. NRAs use **LCM** (life cycle management) by implementing **LCA** (life cycle assessment) **LCCA** (life cycle cost analysis) and **SCB** (social cost benefit) to assess and compare a range of sustainable road constructions. Currently, the implementation degree of these tools within NRAs is still low. Therefore the desired research proposal shall focus on the steps that are necessary to realize practical, correct and reliable estimation of both sustainability and durability of road constructions.

The method for calculating the sustainability of road constructions is described in EN 15804 and yields Environmental Product Declaration (**EPD**). Recently, for road materials, a more specific method, that is based both on EN 15804 and other key performance parameters, has been developed (CWA 17089 **-** Indicators for the sustainability assessment of roads). LCA and LCCA calculations were performed (AllBack2Pave) as part of previous CEDR transnational research and tools to calculate LCA's (LICCER, SUNRA, CEREAL and MIRAVEC) were developed. Despite the availability of both the tools and the (pre-) standards, the results of sustainability calculation of asphalt constructions are disputable due to; poor detailing, no consensus and/or lack of reliable data. Another difficulty is the definition of system boundaries with respect to the decision making situations and the level of inclusion of externalities and upstream impact.

The assessment of performance and durability of asphalt materials (the benefits) in the analysis is an important aspect of these calculations that need detailing and consensus. The durability of green asphalt may be determined by:

1. **Laboratory tests.** The basic assumption is that if the results of performance tests of bitumen and/or asphalt are identical to that of the standard materials, then the life time of the two materials will be identical. This method is often used if the 'new' material does not differ significantly from the standard 'non-green' asphalt.
2. **Accelerated pavement tests.** Results of the testing using the equipment present at BASt (MLS30), STUVA, VTI, TU Delft, or others may be used (see Annex B).
3. **Test sections.** Results may be obtained by extrapolation during lifetime or after end of life. NRAs will support this part of the research by the provision of test sections.
4. **In-service use (not test sections).** Some countries already use green materials on a large scale and can provide information on LCC and LCM analyses that can be considered for use in other countries.

5.1.2 Problem

As the costs and reliability of each of the four methods can vary significantly, NRAs are likely to use different weighing factors in LCM to compare results obtained by the different approaches. Even the performance on large test sections or on in-service roads can be difficult to compare due to the variation in local situations. At present only limited guidance on the use-of, and comparison of the mentioned methods is available. However, at least a qualitative analysis from existing results within CEDR and national projects is available.

The main challenges are:

- To provide guidance and reliable durability data for LCA and LCC(A) to clarify the efficiency of the material, maintenance and construction techniques for the infrastructure provider.
- To fill in gaps that currently hinder implementation of correct and reliable estimation of sustainability and durability. The NRAs have with respect to this identified the following needs:
    - Obtain comparable sustainability and durability databases. NOTE: it is well known that quality of workmanship, climate change and new materials may influence the durability. Therefore, it is appreciated if these effects are included in a lifetime distribution curve.
    - Identify missing data. If possible fill in the gaps by performing measurements or by estimations.
    - Formulate additional calculation rules to obtain more reliable results.
    - Simplify EPD calculation rules if possible.
    - Validation of available data.
    - Validation of several tools; are calculation results comparable?

5.1.3 Expected output

To support a number of CEDR NRAs in considering the use of “green asphalt”, the following outputs are expected:

- Recommended practice for LCA and LCC(A) for green asphalt by individual NRAs.
- Exchange of data and results on efficiency considerations on a transnational level.
- Accepted methods to include reliable durability values for use in the LCA and LCC(A)

5.2 Topic B: Simplifying the use of reclaimed asphalt pavements (RAP)

5.2.1 Description

The aim of this topic is to support NRAs in the simplification of the use of reclaimed asphalt pavements (RAP). In many European countries, the allowed percentage of reclaimed asphalt (RA) in new hot mix asphalt layers is limited to maximum 30% which means that these criteria limit the share of RAP in new construction.

In the last three decades, a number of projects have investigated the use and percentage of RA in new asphalt courses and the required quality of recycled materials. However, a number of questions remain to be resolved.

The Re-Road project stated that "more information regarding the durability of different types of asphalt mixtures, including those incorporating reclaimed asphalt, would be extremely useful" for the prediction of the "likely lifespan of materials" ... "since the rate of replacement of materials can be very significant in environmental terms."

In the AllBack2Pave project, it was pointed out that the heterogeneity of the RA aggregates plays an important role when designing asphalt mixes. For wearing courses high quality aggregates with high resistance to wear/abrasion (polishing) are needed. Properly milled (i.e. layer by layer) and stockpiled RA is a mandatory prerequisite in order to produce durable asphalt wearing courses with high content of RA. One possible solution is to allow the use of a high percentage of RA in wearing courses only if the RA material is sourced from the same location and layer where the new mix will be placed. This results in the need to have appropriate test methods that are quick and reliable for the proper identification of RA in the recycling process chain.

In the COREPASOL project it was found out that "with respect to the public authorities it might be of importance if different approaches could be compared, i.e. cold recycling with new surface layer vs. mill and fill etc."

5.2.2 Problem

Despite the promising results of these projects, pavement recycling techniques are still not widely employed in most European Countries. Possible reasons for this include the lack of long-term performance data from which the expected service life can be derived and a lack of guidelines/best practices for production, construction and quality control of pavements with high content PA.

At present, the amount of stock-piled milled asphalt is increasing in most European countries as only a limited percentage of the milled asphalt is currently used for new asphalt production. Large areas are needed to store the remainder. This material is exposed to weathering, resulting in degradation due to ageing, possibly resulting in the need to down-grade of the recycled material to lower pavement courses.

Considering economic as well as environmental aspects, possibilities of maximising the use of reclaimed asphalt are needed. Horizontal recycling, whose aim is to apply the recycled layer to the same position in the new pavement, can be an effective method. The main concerns for the practical application of this approach are the durability of wearing courses containing a high RA amount and the technological issues of mass production in asphalt plants.

The combination of low temperature production methods with recycling has lead to some success in the production of wearing and binder courses with up to 90% RA material. However, the issue of durability and its implication on the development of reliable life cycle cost models requires more investigation and research. Beside the hot and warm methods, cold recycling is another possible technology that has the potential of 100% RA usage plus the advantage of in-situ production. It can successfully deal with a wider variation of RA when compared to hot and warm methods, and has lower energy consumption. Latest project results show that by cold or semi-warm recycling it is possible to achieve high percentages of RA in the mixture yet still maintain a high quality of recycled material.

New pavement sections where the ‘conventional’ base layer is substituted with thicker layers of a cold recycled base course may also be considered when constructed with a thin top layer comprising virgin materials.

In summary; the main reasons why most NRAs hesitate to implement these techniques and materials are:

- The lack of appropriate standard test methods to characterise and assess the performance of recycled mixes
- The absence of a practical unified approach for structural design of pavements containing cold recycled layers.
- The absence of reliable durability data and/or models for hot/warm mixtures containing high amounts of RA (see subtopic A).
- A lack of clarity on some technological issues of mass production in asphalt plants, such as the installation of parallel drums or adoption of the appropriate warm mix technology.
- The difficulty of matching the use of RAP to hot mix asphalt standards. A major drawback is that the RA composition differs from stockpile to stockpile whereas harmonized European hot mix asphalt standards have narrow bands for compositional changes.

Thus, there is an urgent need for reliable methods to predict the performance of asphalt layers containing RAP, based on standard laboratory test results. To date, existing standards and methods that have been developed for conventional hot asphalt mixtures are applied to recycled mixes which, in some cases, has led to unsatisfactory and unreliable laboratory results. This is particularly true for cold recycled mixes as their characteristics and behaviour are inherently different when compared to hot and warm mixes. It is therefore necessary to adapt existing and/or to define new test methods based on the characteristics of recycled mixtures, building on the results of projects like AllBack2Pave and FunDBitS. Simplified and accurate methods that incorporate quality control of RAP at each stage (testing of the milled and stock-piled material, and testing before recycling and re-use) will result in more reliable and predictable characteristics of these materials and will thus lead to a higher acceptability of RAP.

The main challenges for the simplification of the use of RAP are:

- Reduction of the barriers for the use of RAP by adapting existing test methods developed for standard hot asphalt mixes.
- Development of reliable test methods to model parameters and long-term field performance data for cold recycled materials. This will enable to the definition of “transfer functions” to convert laboratory test results to field service life.
- Minimising the energy needed for hot and warm recycling processes, and thus enable an increase of the percentage of RA in asphalt mixtures.

5.2.3 Expected output

To support CEDR NRAs in the simplification of the use of RAP, the following results are expected in the projects:

- Straightforward quality assessment procedures for RA.
- Proposals to increase the quality of RA (such as the use of rejuvenators, and/or its components).
- Validation and, if necessary, adaptation of existing test methods for testing of recycled asphalt. These will need to be simple, precise and practical.
- Practical instructions for structural design of pavements containing recycled layers.
- Definition of performance tests and their boundaries to assess the life-span of recycled asphalt courses.
- Reduction of the energy consumption for the recycling process of asphalt mixes.
- A demonstration of the recycling and installation processes and the reliability of new approaches as well as the durability of the recycled materials by investigating the likely lifespans of materials containing RA.
- Assessment of the environmental impact of methods to upgrade RA.
- Development of new construction methods that maximises the use of RA in new asphalt layers.
- In-situ assessment of the short-term performance (characteristics after installation to evaluate and validate laboratory test methods for materials characteristics and performance). Demonstration sites will be provided by the participating NRAs. (Note: Long-term assessment of these test sites is intended but is outside the scope of this Call).

5.3 Topic C: Usability of Super Materials

5.3.1 Description

The aim of this topic is to support a number of CEDR NRAs in the usability of “Super Materials”. A ”Super Material” is by definition a “material that has one or more enhanced performances or functional related indexes’. This state can be reached by improving characteristics of existing materials or by the development of a new material.”

Research shows that the addition of aramid fibers to asphalt mixes can lead to an increase of the performance against permanent deformation, fatigue and thermal cracking. As fatigue failure is normally the main criteria for structural design of flexible pavements, increasing the fatigue life of the base or binder layers should result in higher service lives. In addition to the positive effect on fatigue, increasing the resistance of the mix to permanent deformation can also be an advantage. Concentrated heavy axle loads increase the risk of shear failure and rutting in binder layers, especially during periods with high temperatures. Fiber reinforcement might be a solution for this problem.

Thin and ultra-thin hot bonded overlays are becoming ever more popular, but are vulnerable to damage though moisture and freeze-thaw cycles. It is considered that fiber reinforcement might improve the durability of these thin layers, and also cold-applied micro surfacing.

Another application of fiber reinforcement is to increase the durability and to compensate the possible weaknesses of recycled materials. This may result in an increase of RA usage, and is an area for more research on material characteristics.

5.3.2 Problem

To move fiber reinforcement from theory to practice, a number of issues are to be considered, *inter alia*

(a) different pavement sections based on the position of reinforced layer/layers (as wearing, binder or base course),
(b) the possible increase of the performance and service life of each pavement section, and
(c) the mixture characteristics required for this improvement.

Mass production of reinforced mixes and laying methods are also areas requiring research, as is the recyclability of reinforced layers. In this respect LCA may be utilized to assess material sustainability. At the end of the project, once pavement scenarios containing reinforced layers are defined, a LCCA is required.

Nano-technology is revolutionizing the material industry as nano-particles can impart extraordinary properties to materials. In asphalt mixes, nano-particles can be applied as additives, and although the filler has the smallest portion of an asphalt mix, it has an enormous influence on its characteristics and performance. Nano-fillers can easily penetrate the thin film of bitumen around the aggregates and change the properties of the resultant mortar. Nano-clays appear to have a beneficial impact on the high-temperature properties of asphalt binders modified with these materials. Nano-graphite particles can increase the conductivity of the mix which can be used in healing purposes.

As with other pavement materials, when considering the application of nano-materials, it is always of utmost importance to assess their environmental as well as their health and safety impacts throughout their ‘life cycle’ from installation to recycling.

The main challenges for the research on the “Usability of Super Materials” are:

- Optimising the position(s) of fibre-reinforced layers in pavement construction.

- Assessment of sustainability and recyclability to include environmental and health and safety impacts.
- Improved understanding of the mechanism through which the ‘Super Materials’ function, and thus achieve greater use of these materials in practice.

5.3.3 Expected output

The main goal of this research is to evaluate the possible benefits of “Super Materials” on pavement’s performance. To support CEDR NRAs in the usability of Super Materials, the following outputs are expected:

- A literature review of existing research on different fibers for the reinforcement of asphalt mixes including the application of nano-materials in asphalt technology.
- The definition of possible applications of “Super Materials” in a pavement system.
- Practical instructions for structural design of pavements containing ”Super Materials”.
- Assessment of production, preparation and laying of modified asphalts (in the laboratory and on test sites) with consideration of health and safety aspects.
- Methods to assess the long-term performance of “Super Materials”.
- Recyclability of “Super Materials”.
- In-situ assessment of the short-term performance (characteristics after installation). Demonstration sites will be provided by the participating NRAs. (Note: A long-term assessment of these test sites and the validation of the LCCA assumptions is intended but lies outside the scope of this Call)

6 Overview of current and previous activities

A general overview of current and existing relevant research projects undertaken across Europe and other sources of information are outlined in Appendix A. These resources and subsequent reports will provide the starting point for proposals submitted in response to this Call and proposals will be evaluated on this basis. **Applicants must not duplicate existing results or ongoing projects**. Proposals should be based on the outcomes and state-of-the-art findings identified in the projects listed below. Failure to take account of available research conclusions will disqualify proposals from this Call.

7 Additional information

The aim of this Transnational Research Programme is to provide applied research services **for the benefit of National Road Administrations** in Europe.

Tests such as pavement tests may be carried out at test facilities such as those listed in Annex B. In the case that tests are part of a proposed project, applicants are asked to attach a Letter of Intent (LoI) from the test facility.

It is foreseen that project coordinators will meet the PEB to present the progress of the project once per year. Additionally, be prepared to submit papers to conferences (like TRA or FIRM). Consider these costs in your budget.

The target budget provided by the participating National Road Administrations for this programme is **EUR 2.250,000**.

Please refer to the **Guide for Applicants (GfA)** for full details of how to submit proposals in response to this Call.

Appendix A: Existing projects and resources

General references

- U.S. Department of Transportation – Federal Highways Administration "Towards Sustainable Pavement Systems: A Reference Document" FHWA-HIF-15-002 https://www.fhwa.dot.gov/pavement/sustainability/hif15002/hif15002.pdf
- CEN Workshop Agreement "Indicators for the sustainability assessment of roads" CWA 17089:2016
- PIARC Committee D2 Road Pavements *"Green Paving Solutions and Sustainable Pavement Materials"*

Topic A: Social cost-benefit analysis of "green asphalt" (RWS)

Call 2014: Integration of social aspects and benefits into life-cycle asset management (ISA-BELA): http://dratproject.eu/

Life cycle considerations in EIA of road infrastructure (LICCER): http://www.cedr.eu/liccer-project-results/

Evaluation of existing CO2 tools for roads (CEREAL): http://www.cedr.eu/cereal-project-results/

STARS Scoring Traffic at Roadworks: http://www.cedr.eu/stars-project-results/

Road Sustainability and Energy Eco-efficient Management of Roads (Energy) (SUNRA): http://www.highways.gov.uk/knowledge/projects/era-net-road-sustainability-and-energy-eco-efficient-management-of-roads-energy/

Evaluation and Decision process for Greener Asphalt Roads (EDGAR): https://www.ntnu.edu/edgar

Tomorrow's Road Infrastructure Monitoring & Management (TRIMM): http://trimm.fehrl.org/index.php?

Modelling Infrastructure Influence on Road Vehicle Energy Consumption (MIRAVEC): http://www.cedr.eu/miravec-project-result/

Ialcce symposium 2016 Delft Session Construction in the context sustainable development: http://www.ialcce2016.org/wp-content/uploads/2016/05/IALCCE-program-2016.pdf

CEN Workshop Agreement "Indicators for the sustainability assessment of roads" CWA 17089:2016

PIARC Committee D2 Road Pavements "Green Paving Solutions and Sustainable Pavement Materials" present work cycle (2016-2019)

Topic B: Simplifying the use of RAP

Toward a sustainable 100% recycling of reclaimed asphalt in road pavements (AllBack2Pave): http://www.cedr.eu/strategic-plan-tasks/research/cedr-call-2012/call-2012-recycling-road-construction-post-fossil-fuel-society/allback2pave/

Cold Recycling Bitumen Stabilized Pavement Solutions (COREPASOL): http://www.cedr.eu/strategic-plan-tasks/research/cedr-call-2012/call-2012-recycling-road-construction-post-fossil-fuel-society/corepasol-project-results/

Effects of Availability on the Road Network (EARN): http://www.cedr.eu/strategic-plan-tasks/research/cedr-call-2012/call-2012-recycling-road-construction-post-fossil-fuel-society/earn-project-results/

End of Life Strategies of Asphalt Pavements (RE-ROAD): http://re-road.fehrl.org/

DIsmantling and RECycling Techniques for road MATerials – sharing knowledge and practices (DIRECT-MAT): http://direct-mat.fehrl.org/

Functional durability-related Bitumen Specification (FunDBitS): http://silnice.fsv.cvut.cz/fundbits/

Topic C: Usability of Super Materials

Mix Design of Polymer-modified and Fiber-reinforced Warm-mix asphalts with high amount of reclaimed asphalt pavement.TRR, No.2523, 2015, pp.3-10

Performance of Fiber-Reinforced Polymer-Modified Asphalt Two-Year Review in Northern Arizona: https://www.researchgate.net/publication/309130134_Performance_of_Fiber-Reinforced_Polymer-Modified_Asphalt_Two-Year_Review_in_Northern_Arizona

Performance Comparison between Fiber-Reinforced and Rubber-Modified Asphalt - See more at: http://ascelibrary.org/doi/pdf/10.1061/9780784479742.097#sthash.CHhCgMLI.dpuf

Evaluation of Synthetic Fibers in Asphalt Pavements: https://static.tti.tamu.edu/tti.tamu.edu/documents/319-1F.pdf

Nano-clay-modified asphalt materials: Preparation and characterization: http://www.sciencedirect.com/science/article/pii/S0950061810003193

Effect of using Nano-clay to improve Asphalt materials: http://seekdl.org/nm.php?id=7156

Evaluation of Moisture Susceptibility of Nano-clay-Modified Asphalt Binders through the Surface Science Approach - See more at: http://ascelibrary.org/doi/abs/10.1061/%28ASCE%29MT.1943-5533.0001228#sthash.YRE23VxC.dpuf

Nano-clays for binder modification of asphalt mixtures: http://citg.home.tudelft.nl/fileadmin/Faculteit/CiTG/Over_de_faculteit/Afdelingen/Afdeling_Bouw/-_Secties/Sectie_Weg_en_Railbouwkunde/-_Leerstoelen/Leerstoel_Wegbouwkunde/-_Publicaties/-_Publicaties_2009/doc/nanoclay_rilem.pdf

Research on Properties of Graphite Oxide Nano-fine Particles Modified Asphalt: http://www.ijera.com/papers/Vol5_issue6/Part%20-%205/T5605119121.pdf

Carbon nanotubes-modified asphalt binder: preparation and characterization: http://www.ijprt.org.tw/reader/pdf.php?id=459

National programmes

Topic A: Social cost-benefit analysis of "green asphalt" (RWS)

Netherlands: Bepaling van de milieuprestaties van gebouwen en gww-werken (check for English version)

Topic B: Simplifying the use of RAP

Low Energy and Emission Asphalt Pavements (LE2AP): http://www.bamle2ap.com/

Appendix B: Example list of test facilities

ID	Owner	Scope	Type	Technology domain
Austerfjord Exposure Site	NPRA (NO)	Ferry quay in western Norway that supports various types of experiments, research and development, primarily for materials and durability	Permanent testing facility for marine exposure	Construction and maintenance
DuraBASt	BASt (DE)	An area for testing and demonstration of new roads as well as a reference for a variety of measurement vehicles	Permanent, separate area not under real traffic	Construction and Maintenance
DVT Randstad-Antwerp-Brussels-Luxembourg	RWS (NL), AWV (BE-FL), (BE-WL), PCH (LU)	A segment of the TEN-T core network (roads), located in the Benelux Union. Roadcodes: tbd.	Permanent, under traffic	Construction and Maintenance
E8 Borealis Pilot Road	NPRA (NO)	The E8 road from the coast near the city of Tromsoe to the Finish border shall be used for demonstration of ITS-technology, services and intelligent solutions for operation and maintenance. Collaboration with similar project in Finland known as the E8 Aurora project.	Permanent road. Project 5 yrs. (estimated)	Construction, operation and maintenance.
Lintrack	TUDelft (NL)	Pavement testing		
Runehamar Test Tunnel	NPRA (NO)	Tunnel that supports various types of experiments, research and development within fire protection	Permanent testing tunnel facility	Construction, operation and maintenance
Test site Trondheim	NPRA (NO)	The test site contains streets in the city of Trondheim equipped with C-ITS stations. This corridor is established for testing C-ITS in urban areas. Outside the city there are defined a corridor at E39 for testing C-ITS under rural condition, at a two-lane road with medium traffic density. This corridor contains long tunnels, bridges etc. It should be interesting for several use cases. A part of this corridor is equipped with infrastructure suited for both development and tests of ITS technology and services. This part of the test site is offered for use for developers/private companies	Permanent road	C-ITS
Transport Research Laboratory (TRL)	Transport Research Foundation (UK)	Provides research, consultancy, testing and certification for all aspects of transport.	Permanent, separate area not under traffic	Multiple
TU Delft	TU Delft (NL)	In-situ testing, test sites on highways.	Permanent, under traffic	Construction, operation and maintenance
WinterLab	NTNU	Facilities for testing of winter conditions, snow, ice, sand, friction, tire winter performance, sensor testing	Permanent university lab	Construction, operation and maintenance