Pavement Performance & Remediation Requirements following Climate Change (P2R2C2)

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Inside

1. Overview

The partner highway administrations that comprise "ERA-NET ROAD" (ENR) funded a number of projects concerning the impact of climate change on highways as part of their programme to coordinate and implement road research across Europe. The partners in ENR are listed on the next page.

With the acronym P2R2C2 (Pavement Performance and Remediation Requirements following Climate Change), the partners listed on the left of this page studied the likely effects of climate change on road pavements. This brochure provides a summary of their findings.

2. Aims of Project

The aims of the project were to

- study the likely differences in moisture (water) condition in the pavements of roads in Europe, from the Alps and northwards, as a consequence of climate change;
- estimate the likely consequences for pavement and subgrade material behaviour and for whole pavement needs;
- perform this study for a range of representative pavement types and representative climatic zones;
- assess uncertainties to permit risk / vulnerability to be evaluated;
- define options for responding to the changes;
- perform cost-benefit analyses to allow road owners to determine best options for their own situations;
- publish the results – of which this summary is one means.

The project was performed by a combination of literature review, laboratory evaluation of materials, computational

Partners in P2R2C2

University of Nottingham (leader, UK)
SINTEF (Norway)
VTT (Finland)
ZAG (Slovenia)

studies of pavement structural and hydrological performance and by the development of recommendations suitable for implementation by national road owners into their specifications and design guides.

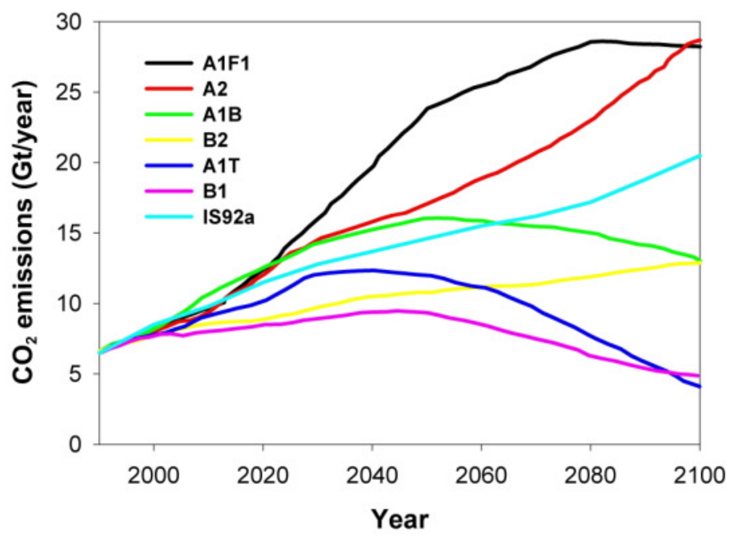
Partners in ERA-Net Road

United Kingdom
Finland
Netherlands
Sweden
Germany
Norway
Switzerland
Austria
Poland
Slovenia
Denmark

(www.road-era.net)

3. Climate Change

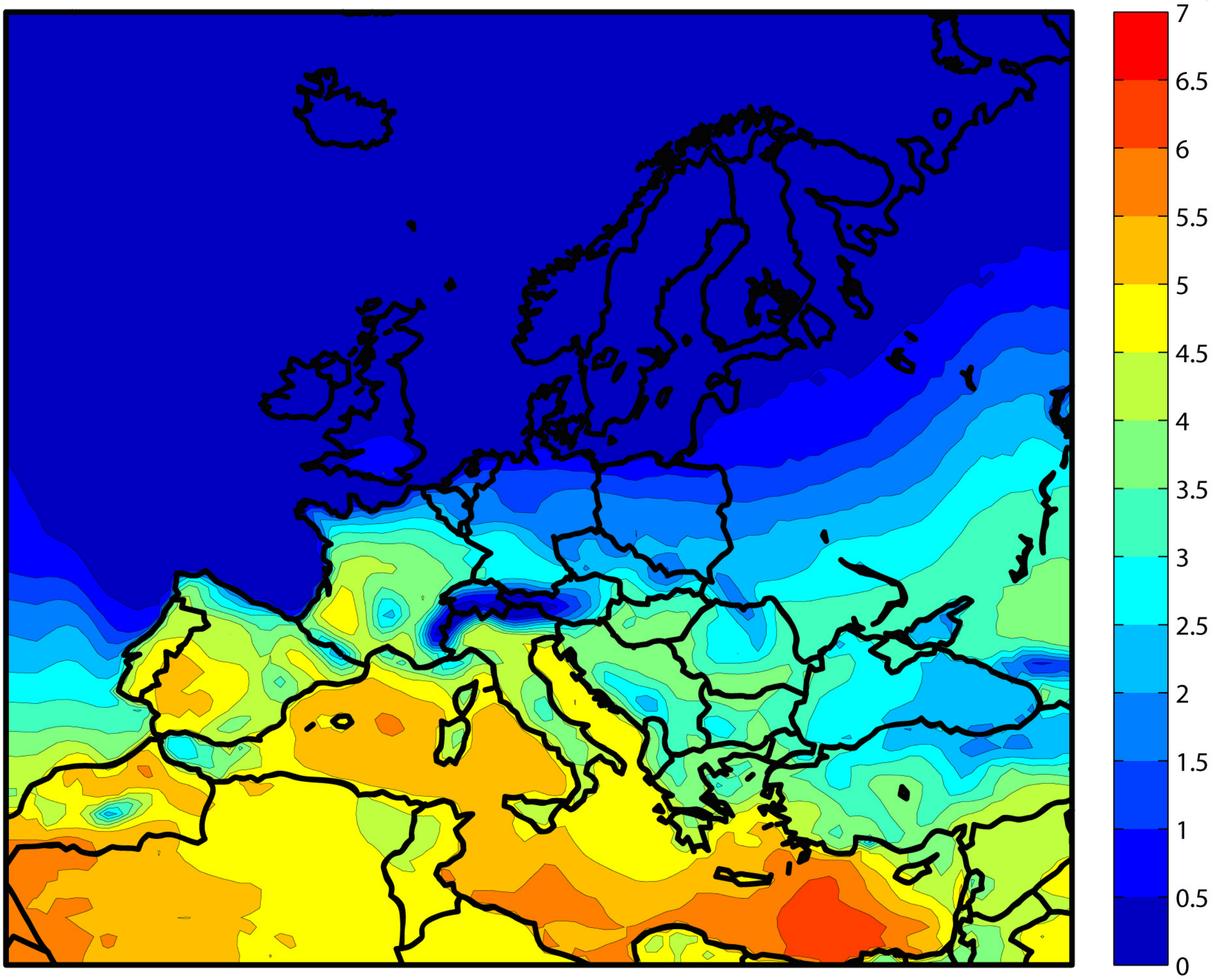
Anticipated climate change in Europe over a 110 year period from the mean climate in 1961-1990 to the mean climate in 2071-2100 was estimated using two (emissions) scenarios (A2 and B1 in the figure below) and two computational approaches. The impact of the resulting changes in climate was then estimated for pavements and pavement-related infrastructure, north of the Alps, in order to determine the consequences for road owners.



Because no-one is sure what future emissions will be, the prediction of future climate will, inevitably, be hugely uncertain

The predictions of climate change show considerable local variation. Nevertheless, it is possible to summarise the predicted manifestations of climate change in the study region as:

- Temperature rise. In the southern edge of the study area the greatest deleterious impact will be hotter summers. In the far north it will be the reduced length of winter. In much of the Nordic and adjacent countries the principal deleterious effect will be the reduction in zero degree transitions meaning pavements will spend significant periods with unfrozen surface layers during the winter.



An example of predicted climate change:
Change in number of hours×degrees >25°C between the 1960-90 average value and the 2070-2100 average value. This gives an indication of how much more severe summers will be. For Europe north of the Alps it is France, southern Germany and the southern Czech & Slovak republics that experience the greatest change. Key is in 5 000 hour×degree increments. Country boundaries are not to date!

- Little change in total rainfall (or snowfall) except in northern Poland, the Baltic states, the Nordic states and Scotland. Greatest increases are expected in the Atlantic coastal areas of Norway and Scotland but, proportionately to current rainfall levels, the increase there will be similar as in other parts of northern Europe – 20-30%. The Alps will also experience an increase.
- Increased rainfall intensity in most areas.

At the time of writing the political will to ameliorate change seems relatively small, so the estimated climate changes computed, and on which our report is based, may be an underestimate of those that will be experienced.

4. Effects on Pavements

It is noted that the life cycle of the pavement is much less than the time span over which climate change will have a statistically dependable influence on pavement performance. Only for the pavements with longest life, or for the lower layers that may not be touched during future rehabilitation and reconstruction, do road designers need to change their practice at present.

However, if current practice is not to be progressively changed at times of major pavement rehabilitation during the next 110 years, then the effects of these changes on pavements constructed, managed and trafficked as at present might be:

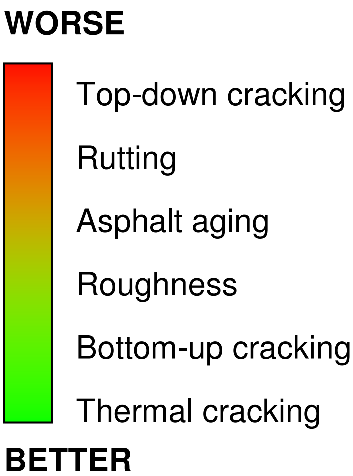
In most areas greater heat will lead to better support conditions but softer asphalt that is more prone to rutting

- In areas where rainfall is unchanged then subgrades and aggregate layers should be drier on average, because warmer temperatures should increase evaporation. Even in wetter areas, the increased rainfall intensity is likely to result in greater run-off so increased net infiltration to the subgrade and aggregate should be small or even negative. A small improvement in pavement support is therefore anticipated in most locations.
- Temperature and rainfall increase will be a challenge for asphalts. Softer materials more prone to rutting and stripping can be expected.
- Where users depend on frozen roads during winter, the length of the frozen period will decrease in the far north with a briefer spring thaw – a mixed problem and benefit. To the south, in much of the Nordic area, frozen road structures may disappear altogether in some years. Periods during the winter when the surface layers aren't frozen will become normal. Spring thaw problems will be likely to become less problematic, but many thin and

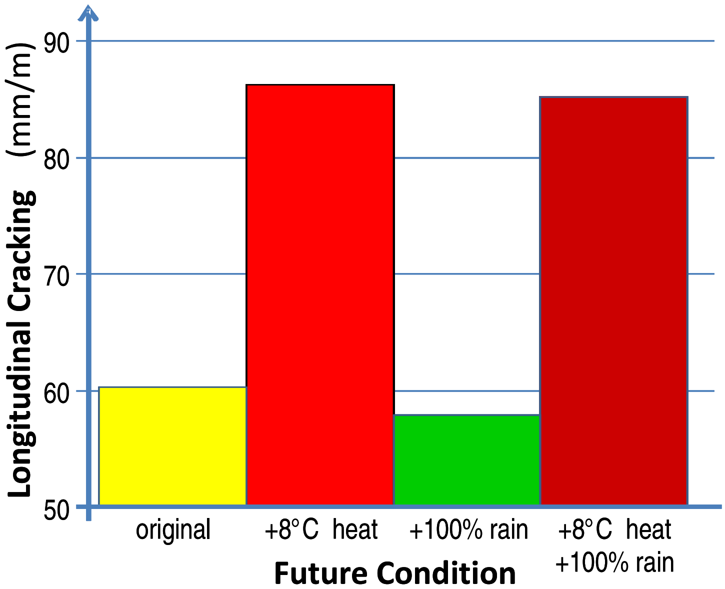
unsealed pavements will need upgrading to provide a reliable, high, bearing capacity all winter long.

Freezing can pull large volumes of water into an unsealed road which then softens excessively during spring thaw because of inadequate, or impossible, drainage. At the moment the central parts of the Nordic countries experience this during spring. In future they may experience less severe, but longer lasting thaw problems as freezing and thawing occur repeatedly in a warmer winter

- In coastal and low lying areas raised water tables may be experienced due to points at which flood waters collect or due to raised sea levels. Road raising or special reinforcement techniques will be needed locally to address this problem.
- For major, asphaltic, highway pavements, the structural response is mixed. Without mix or structural adaptations, top-down cracking is expected to be the greatest problem (figure below), whereas bottom-up and thermal cracking issues will become less (see figure alongside).



Ranking of likely structural impacts of climate change on a major asphaltic pavement



Longitudinal, top-down cracking after 20 years for a major pavement (325mm asphalt) subjected to constant 'worse-case' conditions

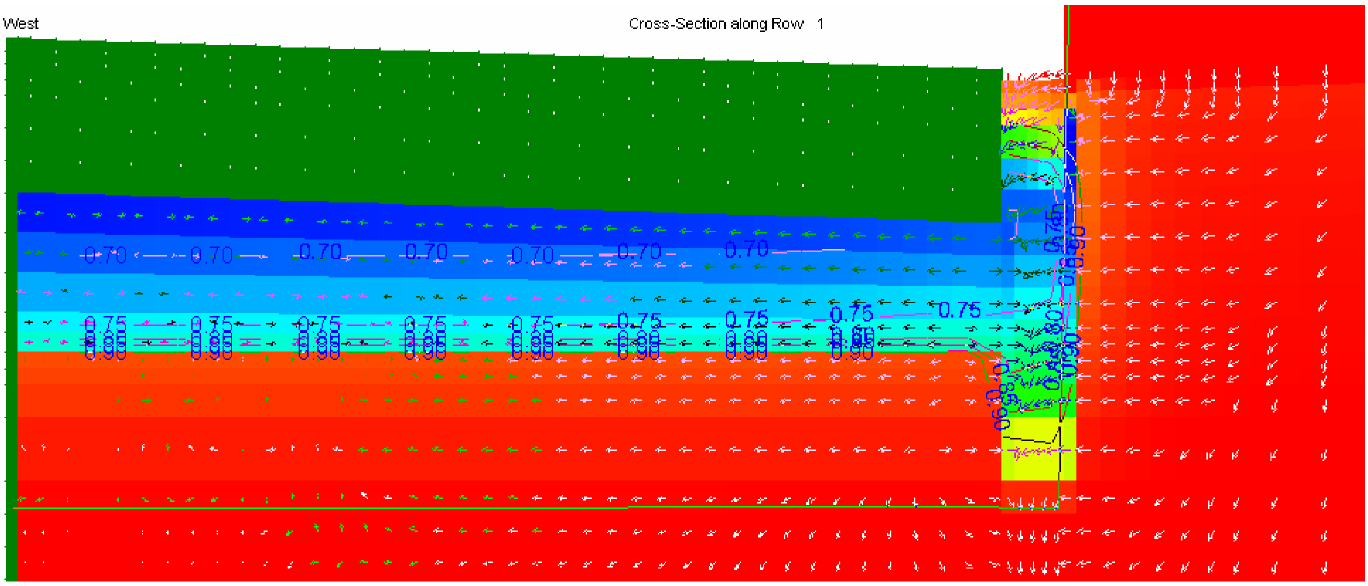
5. Required Responses

The research team performed literature reviews, materials assessments, pavement designs and seepage calculations to determine the likely effect of the changes in water condition and temperature on typical pavement constructions. The results were used to define the responses that pavement designers and pavement maintainers should take at design, construction, materials selection, maintenance and operational stages.

Using this information, the research team found that the appropriate responses to the anticipated effects of climate change:

- will be achievable, in most cases, by routine material formulations that can be employed at the next reconstruction/rehabilitation event,
- will need new design criteria regarding temperature and return period of storm flows to be developed (regionally specific),
- will need more attention paid to drainage systems, particularly to make them self-cleaning and easily inspectible,
- are likely to include, in the mid and southern parts of the Nordic countries, stabilisation of unsealed pavements, or overlaying by bound layers, and

"There are three things that a road requires – drainage, drainage and more drainage"
Arthur Cedergren, 1974.



Model of an asphalt-surfaced pavement showing percolation flows at the end of a heavy rain event. Note the inability of the lateral drain to carry the run-down to the outlet pipe fast enough. Also note the undesirable movement of water from the lateral drain into the subbase. Redder = more saturated, Blue = drier.

- may necessitate more rut-resistant and stripping-resistant resurfacings on 'perpetual pavements' than originally planned. Such materials are readily available at a minimal cost differential.

Rutting and cracking of a distressed pavement with poor drainage

Inadequate capacity of a sub-surface drain run after an intense rain storm will force excess run-off to find its own route, with undesirable consequences

6. Results in Context

However, concentrating on these technical issues is unlikely to be a significant problem, nor a great economic challenge when compared to the necessary response from highway engineers to the wider social, economic, technical and political impacts on pavements that can be guessed at over the next 110 years. Demographic change, transportation method, funding models, journey patterns, vehicle type, demands of users and demands of funders are expected to be far more of an influence on future pavement engineering. Some of these impacts will likely be driven by climate change itself.

7. Further Information

Further information is available from our web-site address (at the bottom of the page). It's the place from which you can download our 9 detailed reports and our summary report. These are listed below.

Number	Title
1	*State of the art of likely effect of climate on current roads*
2	*State of the art of materials' sensitivity to moisture change*
3	*Alternative materials and methods to enhance resistance to climate change*
4	*Soil wetting-drying study*
5	*Study of water effects on asphalt and porous asphalt*
6	*Climate change projections for variables affecting road networks in Europe*
7	*Analysis of pavement structural performance for future climate*
8	Not used
9	*Pavement response to rainfall changes*
10	*Future rehabilitation and maintenance & cost-benefit study of alternative solutions*
11	*Overall advice and summary*

The University of Nottingham

Project Coordinator
University of Nottingham, UK

ZAG LJUBLJANA

ZAG, Slovenia

VTT

VTT, Finland

SINTEF

SINTEF, Norway