



COST 351

WATMOVE

Water Movements in Road Pavements and Embankments

Report Title: **First Annual Report, 2004**
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Output of Working Group:
Date: **1 Dec 2004**
Version Number: **3**

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Executive summary

The brief report gives an overview of the activities of the COST 351 Action on “Water Movements in Road Pavements and Embankments”. The Action’s team includes representatives of 18 countries, an increase from 14 which started the Action in late 2003. The Management Committee comprises experts from a wide range of disciplines and representing a diverse cross-section of the stakeholders of the topic.

The team have engaged in a detailed study of the tasks required of them by the Memorandum of Understanding and gave concluded that they should address:

- The lower pavement layers and the upper part of the subgrade, in the zone of influence of traffic loading, extending to the water table where contaminant seepage is of concern,
- Producing a textbook as the principal final output, suitable for practising engineers,
- Collecting in-situ performance data whenever possible, particularly on best-practice,
- Run-off water as well as seepage water as regards contaminant movement, and
- Heat-flow so as to be able to understand water flow driven by freezing or thawing.

The Management Committee has met three times (including its start-up meeting) with the Working Groups meeting sequentially with the Management Committee on that body’s second and third meetings as well as alone on two additional occasions. Meetings have been held in Bruxelles, Liège, Kobenhavn, London and Lisboa. The working groups have defined in considerable depth the topic matter to be presented by the Action and have already commenced drafting text. In parallel, a questionnaire has been prepared in draft to seek out case histories and best-practice. One short-term scientific mission has been performed and a web-site established for members.

In 2005 the principal tasks to be addressed are:

- Continued drafting of the text book.
- Issuing of the questionnaire and assimilation of the replies.
- Arranging of a workshop in late 2005
- Issuing a Newsletter in time for the BCRA conference in July 2005.

Two more Management Committees (with Working Group meetings) and two other sets of Working Group meetings are envisaged, as well as the workshop and some further short-term scientific missions. It is expected that the web-site will be further developed.

1 Introduction

COST Action number 351 held its first Management Committee on December 19th 2003 in Bruxelles. Since then the members have met twice further and have elaborated the details of the tasks that need to be addressed. In addition, working groups of the Action have met on four occasions, two in conjunction with the Management Committee meetings and two separately. This report summarises the progress that has been made against the objectives.

2 Membership

The Action entered into force on the 12th June 2003 but, due to fiscal constraints, did not commence active work until the first meeting of the Management Committee on December 19th 2003, despite the Memorandum of Understanding (MoU) having been accepted by the COST organisation in 2002. At the time of commencement the Action had six signatories and a further eight countries in process of joining. Since the start, four countries have petitioned the existing members for permission to join the Action (Poland, Serbia and Montenegro, Spain and Romania). The existing members have been pleased to accept their applications and the first four countries have completed the necessary formalities.

At the time of writing (mid November 2004) there are, therefore, 17 signatories to the Action with one (Romania) in process of signature. The Action is currently due to end on the 18th of December, 2006. Table 1 list the signatory countries and the date of joining the Action.

Table 2.1 Membership of COST351

Country	Date of Signature of MoU	Membership Status
Belgium	11/06/2003	Confirmed
Croatia	12/06/2003	Confirmed
Czech Republic	21/04/2004	Confirmed
Denmark	29/01/2004	Confirmed
Finland	11/06/2003	Confirmed
France	11/06/2003	Confirmed
Greece	02/06/2004	Confirmed
Iceland	01/07/2004	Confirmed
Norway	29/01/2004	Confirmed
Poland	29/01/2004	Confirmed
Portugal	31/03/2004	Confirmed
Romania	Not yet signed	Application progressing
Serbia and Montenegro	21/04/2004	Confirmed
Slovenia	11/06/2003	Confirmed
Spain	08/10/2004	Confirmed
Sweden	29/01/2004	Confirmed
Switzerland	10/09/2003	Confirmed
United Kingdom	29/01/2004	Confirmed

3 Management Committee

Most of the member countries send two delegates to the Management Committee (MC). In the case of a few countries three delegates are identified, two of them being present at the MC meetings. This allows for illness or for other commitments. The current list of members is shown in Table 3.1.

Table 3.1 List of Management Committee Meeting Members

Name	Institution	Country
Jostein Aksnes	Norwegian Road Administration	Norway
Radu Andrei	Technical University “Gh. Asachi”, Iași	Romania
Torleif Baekken	NIVA (Water Institute)	Norway
Jose Baena	CEDEX (Road Institute)	Spain
Susanne Baltzer	Danish Road Institute	Denmark
Gunnar Bjarnason	Icelandic Road Administration	Iceland
Birgitta Boman	VINNOVA (R&D financing body)	Sweden
Virgil Breaban	“Ovidius” University of Constanta	Romania
Mihael Brencic	Geological Survey of Slovenia	Slovenia
Cane Cekerevac	Ecole Polytechnique Fédéral de Lausanne	Switzerland
Robert Charlier	University of Liège	Belgium
Cyrille Chazallon	University of Limoges	France
Andrew Dawson	University of Nottingham	UK
Sigurdur Erlingsson	University of Iceland	Iceland
Santinho Faisca	IEP (Portuguese Road Agency)	Portugal
Lennart Folkesson	KTH (Royal Institute of Technology)	Sweden
Denis François	LCPC (Road Institute)	France
Beata Gajewska	IBDIM (Road and Bridge Research Institute)	Poland
Kent Gustafson	VTI (Road & Traffic Institute)	Sweden
Åke Hermansson	VTI (Road & Traffic Institute)	Sweden
Pierre Horny	LCPC (Road Institute)	France
Matti Huhtala	Retired (formerly VTT)	Finland
Antonios Kaltsounis	University of Athens	Greece
Aleksandar Kostadinovic	IMS (National Civil Engineering Institute)	Serbia & Montenegro
Cezary Kraszewski	IBDIM (Road and Bridge Research Institute)	Poland
Petra Kurimska	CDV (Transport Research Centre)	Czech Republic

Rainer Laaksonen	VTT (Road Research Institute)	Finland
Lyesse Laloui	Ecole Polytechnique Fédéral de Lausanne	Switzerland
Bojan Leben	ZAG (Civil Engineering Institute)	Slovenia
Teresa Leitão	LNEC (National Civil Engineering Laboratory)	Portugal
Wyn Lloyd	Highways Agency	UK
Nikolaos Michas	Greek Road Federation	Greece
Goran Mladenovic	University of Belgrade	Serbia + M.
Antero Nousiainen	Tieliikelaitos (Road Operator)	Finland
Primož Pavšič	ZAG (Civil Engineering Institute)	Slovenia
Karel Pospíšil	CDV (Transport Research Centre)	Czech Republic
Paulică Răileanu	Technical University “Gh. Asachi”, Iași	Romania
Mate Sršen	IGH (University/ Civil Eng. Institute)	Croatia
Eric van den Kerckhof	BRRC (Road Research Centre)	Belgium
Martin Vojtěšek	CDV (Transport Research Centre)	Czech Republic

The Action’s team has a wide spread of disciplines represented - Geology, Water Resources, Highway Owners & Operators, Materials Engineers and Pavement Designers. This is a strength of the Action. Also, there is a good mix of academic, policy and research institute membership.

Unusually for a COST Action, neither the person responsible for drafting the MoU (Kent Gustafson of VTI, Sweden) were able to stand for election as chair, nor was anyone else from that person’s country. Two candidates were proposed for chairman, Prof. Robert Charlier (Belgium) and Mr Andrew Dawson (UK). The latter was elected as chairman at the first meeting, subject to the UK completing the signatory process (which it did about a month later). Prof. Charlier was elected vice-chair and Prof. Siggurdur Erlingsson, Dr. Karel Pospíšil and Prof. Charlier were elected chairmen of Working Groups (WG) 2, 3 and 4, respectively. At the third MC meeting in Lisboa, Dr Pospíšil handed over chairmanship of WG3 to Dr. Mihael Brencic.

4 Progress in Year 1

4.1 Review of the MoU's Technical Annex

A prime task for the Action, in its first year, has been to grasp the intention of the MoU and seek to put in place a series of activities that will meet the objectives of the MoU, as expressed in its Technical Annex. We have not found this a trivial matter. Indeed, there has been lengthy discussion at our MC meetings concerning the primary requirements of the Technical ANNEX. The following issues were particularly reviewed and the conclusions reached are indicated.

- How much of the embankment should be included in our study? It is evident that we should address water conditions and movements in the pavement structure but less clear as to the thickness of the embankment which would be of interest. Finally, we concluded that the depth of subgrade soil which is sensibly stressed by traffic (no more than approximately 1.5m below the surface or approximately 1m below the pavement) should be the subject of study as far as the water condition and its change is concerned. However, a greater or lesser depth was indicated for environmental matters. Here the depth to the phreatic surface was chosen as the appropriate depth as this would be the point at which contamination would likely be assessed.
- How should the results of the Action be presented? We were (and are) enthusiastic about disseminating our findings to a large audience. We judged that the people we most wanted to reach were road designers and operators in government road authorities, in highway agencies, in design bureaux, etc. For these people a Final Report would probably be rather unappetising. So we concluded that we should attempt to produce a textbook addressing the topic of the Action. The Final Report would then be a much briefer document reporting the progress against the objectives and not reporting the technical outputs.
- Does the MoU want improved pavement performance as a result of our work or does it want improved understanding of the principles and processes of water and contaminant movement and change? The answer is that it is seeking the former via the latter. The difficulty the team faces is ensuring that the work undertaken to meet the secondary objectives listed in the Technical Annex (which cover principles and processes) will, thereby, enable the overall goal to be met. To achieve this, practical application details will receive special attention in the textbook and we will seek to determine best-practice in the area by collating successful and unsuccessful case history information. This will hence be a feature of our data gathering.
- What level of complexity is warranted in the textbook? This point has received much attention. A textbook that seeks to describe principles and processes cannot, in the field of hydrogeology and geo-mechanics, achieve this without covering the relevant theory. Yet we know that many practitioners will be put off use of a book which requires detailed attention to theory. To address this dilemma we aim to provide 'boxes' within the page (probably with a different font) which will allow the more complex theory to be described at the point of use, but 'off-line' as well.
- Which types of water are envisaged by the Technical Annex? Immediate reading didn't make this clear. In so far as water affects mechanical behaviour it would seem that seepage water, through the structure, was envisaged – this is the requirement of

the 4th of the Secondary Objectives. However, the Annex also points out that the water driving such seepage comes, largely, from run-off and will already be contaminated before it enters the pavement / embankment structure. We have therefore concluded that we should address contaminated water run-off, albeit with the emphasis on percolating water in the substructure.

- How should water movements associated with freezing and thawing be addressed? The Technical Annex makes some mention of frost issues but does not suggest a method of study. Accordingly, we have determined that we need to include heat flow issues in our work. In many respects heat flow theory and water flow theory are inter-related, so it would be difficult to exclude a study of heat flow. However, this does extend the work of the Action over and above that originally envisaged.
- The working group arrangements envisaged by the Technical Annex did not seem to help us to achieve the interpretation of our tasks as described above. Accordingly, we decided that WGs 2, 3 and 4 should commence work directly, covering their own literature reviews. WG1 is to manage the questionnaire as an 'agent' of WGs 2, 3 and 4 to avoid respondents having to complete three questionnaires.

4.2 Progress of Working Groups

Working Groups 2 and 4 have met 4 times, WG 3 has met 3 times in 2004. The first meetings were in Liège on 2nd-3rd April, the second on 4th June in Kobenhavn, the third (except WG4) in London on September 17th-18th. The last meetings were held in Lisboa on November 12th. Start-up was a little slower than might have been wished (mostly because of the need to grapple with the issues described in Section 4.1). However, additional funding was secured which enabled the London meetings to be arranged and this allowed the work to accelerate significantly. The Technical Annex envisages the work of WGs 2, 3 and 4 continuing until mid 2006. Given this timetable the work of these Groups is on-schedule.

Working Groups 2, 3 and 4 have identified and revised, more than once, the syllabus to be covered by the textbook. Many of the chapters have been divided up between drafting persons and drafting panels and writing has commenced. An outline of the Contents is given in Annex 1.

Working Group 1 has not formally met as yet. Given its somewhat reduced scope from that envisaged in the Technical Annex, its questionnaire work has been taken up by Ms Suzanne Baltzar. She has undertaken editorial work and issuing of a revise questionnaire jointly on behalf of the other three WGs should take place in early 2005.

Working Group 5 (Dissemination & Reporting) is envisaged by the Technical Annex as commencing in late 2005. However, the chairmen have been meeting prior to the main MC meetings as an ad hoc panel to help direct the work of the Action. We have, in part, done this so as to ensure that dissemination and reporting matters are progressing.

4.3 Short-term Scientific Missions (STSMs)

One STSM took place in 2004 when Prof. Robert Charlier of the University of Liège visited EPFL in Lausanne. This was to contribute to the work of WG4 and sought to advance the coupling between water condition modelling and the mechanical response of the pavement or subgrade to the changing moisture value.

4.4 Web-site

An internal web-site for the Action members has been established by the chairman. A simple to remember web-site address (www.watmove.org) has been purchased, but is not yet operative.

4.5 Budget

At the time of writing the exact figures are not available as they await the expenses incurred by our last Lisboa meetings to be finalised. The original budget was 68 000 Euro. With the additional four member countries by the date of our final meeting and the desire to have an additional WG2 and WG3 meeting in London an increase of this budget to 88 000 Euro was agreed with the COST office. It is envisaged that the end-of-year figures will show somewhat under-budget. The budget agreed for 2005 is 70 908 Euro.

5 Plan for 2005

5.1 Tasks

The chief tasks for 2005 are as follows:

1. to continue with the drafting of the chapters for the text book.
2. to issue the questionnaire, to receive replies and to assimilate the replies.
3. to begin discussions with potential publishers on the basis of an extended contents list for the book
4. to seek to arrange a workshop in late 2005 (partly to promote the Action and partly to draw on expertise outside of the team)
5. to prepare and issue a Newsletter in time for the BCRA conference in July 2005.
6. to deliver these objectives within the 2005 budget.

5.2 Meeting Schedule

Our planned meeting schedule is as follows (with suggested venues):

- 3-4 March WGs (Bruxelles)
 - 14-15 April WGs & MC (Paris)
 - 5-6 Sept WGs (Lausanne)
 - 26-28am Oct..... WGs, MC & Workshop (Madrid)
- Short-term Scientific Missions (STSMs)**

At present three STSM's are envisaged for 2005. Prof. Robert Charlier of the University of Liège intends to visit EPFL in Lausanne to continue his work on the coupling between water condition modelling and the mechanical response of the pavement or subgrade to the changing moisture value. Prof. Siggurdur Erlingsson of the University of Iceland intends to visit EPFL to attempt to integrate frost effect and thawing issues into design and prediction procedures. Finally, Mr Andrew Dawson intends that one of his junior researchers from the University of Nottingham visit another centre (probably the University of Liège) to assist with defining the procedures which should be adopted to enable the prediction of contaminants within seepage waters.

5.4 Workshop

We are currently investigating the possibility of holding a one-day (24 hours, lunch to lunch) workshop on Water Movements in Road Constructions. The aim would be to invite researchers and practitioners to prepare short papers describing research and practical findings. The workshop would be open to anyone, not just Action members and members of their institutions. By this means the Action would be advertised to many others and the expertise of others would become available, in part, to the Action.

5.5 Web-site

The www.watmove.org web-site will be established in 2005 and, as outputs (including this report) become available will be mounted for public use. The web-site is likely to be a main plank in the advertising of the intended workshop.

5.6 Budget

On the basis of the envisaged programme and the venues, a budget somewhat higher than that spent last year is needed. Small increases are required for:

- Full participation of all 18 member countries
- Somewhat larger participation at WG meetings in Bruxelles and Lausanne than in 2004 at Liège and London, as drafting of chapters will form a concentrated effort in 2005.
- Funding required for a workshop session in Madrid in Autumn 2005 (This will be from a separate budget from the main budget for the Action).

The 2005 budget should be sufficient for the first two items, if managed prudently.

6 Conclusions

2004 has been a successful year in building a team to deliver excellent work for the COST351 Action on Water Movements in Road Pavements and Embankments. A sensible strategy and task structure has been set in place and results are already being delivered. 2005 should see significant progress and the commencement of major dissemination in the form of a Newsletter to a key conference, of a workshop in the area of the Action and of a web-site to act as a focus for these activities. This level of activity, and its successful delivery of work that meets the aims of the Action, depends on two things: an enthusiastic team (which experience in 2004 suggests will be forthcoming) and a realistic budget which has now been largely agreed.

Annex I. Draft Contents List of Textbook

Executive Summary

1 Introduction

- 1.1 Background
- 1.2 Aims and objectives
- 1.3 Organisation of report
- 1.4 Work plan
- 1.5 Terminology

2 Relationship Between Water & Roads

- 2.1 typical cross sections
- 2.2 Road run-off
- 2.3 Seepage flows

3 Water flow theory in saturated and unsaturated soils

- 3.1 Groundwater hydrology
- 3.2 Darcy's law (& Forcheimer, including relationships with grading)
- 3.3 The Vadose Zone
- 3.4 Cyclic effects, hysteresis in retention curve
- 3.5 Mechanical effects of water (introduction)

4 Heat transfer in soils

- 4.1 Basic principles
- 4.2 Coupling with fluid flow
- 4.3 frost, ice production or melting
- 4.4 vapour transfer

5 Measurements techniques for water flow

- 5.1 Introduction
- 5.2 Parameters needed, parameters identification
- 5.3 Sampling and access
- 5.4 Laboratory Tests
 - 5.4.1 Moisture content

5.4.2 Permeability testing

5.5 In-situ test methods

5.5.1 Moisture content

5.5.1.1 Gamma ray attenuation

5.5.1.2 Time Domain Reflectometry techniques

5.5.1.3 Ground Penetrating Radar

5.5.2 Permeability

5.5.2.1 Soakaway tests

5.5.2.2 Injection tests

5.5.3 Suction

5.6 Instrumentation

5.6.1 Gypsum blocks

5.6.2 TDR probes

5.6.3 etc

5.7 Experimental investigation: design of material, specificities (cycling, suction / saturation control, thermal control, etc.)

6 Computer modelling for water movement and heat transfer in pavements

6.1 Purpose

6.2 Method

6.3 Limitations

6.4 Available codes

6.5 Examples

7 Contamination of water and soil

7.1 Objectives of chapter

Scope (physical boundaries and subjects covered, not background)

Principles (Source-Pathway-Target)

7.2 Sources of contamination

7.2.1 Traffic and cargoes

7.2.2 Maintenance and operation sources

7.2.3 Pavement & Embankment Materials

7.2.4 Outside sources

7.3 Pathways of contaminant movement & transport processes

7.3.1 Pathways

7.3.2 Physical Processes

7.3.2.1 Saturated transport

7.3.2.2 Unsaturated transport

7.3.2.3 Run-off

7.3.3 Chemical Processes

7.3.4 Biological Processes

7.4 Targets (include examples of real impacts on the following targets)

7.4.1 Soil

7.4.2 Groundwater

7.4.3 Surface Water Bodies

7.4.4 Flora & Fauna

7.4.5 Humans

7.5 Legislation

8 Measurement techniques for contamination detection and evaluation

8.1 Sampling

8.2 Procedures

8.3 Quantification

9 The mechanical effects of water in pavement and its control / theoretical aspects / Mechanical constitutive modelling.

9.1 general objectives, bearing capacity evaluation (strength and deformation), practical consideration versus geomechanical considerations

9.2 example of premature pavement deterioration

9.3 general framework of constitutive models for porous media

9.4 principle of effective stress

9.5 models for sub-grade behaviour, cyclic loading, asymptotic behaviour, fatigue, permanent deformation ... (EP, EVP, Damage...) (cf. COST 337)

9.6 constitutive modelling and partial saturation, suction coupling, water interaction on mechanical behaviour

9.7 mechanical - thermal coupling

9.8 chemo-mechanical interaction, ageing and degradation of pavement, cracking, grade and subgrade.

9.9 conclusions

10 Mechanical behaviour: experimental investigation, dependency on water and moisture

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- 10.1 parameters needed (current modelling versus advanced modelling), parameters estimation, identification
 - 10.2 experimental investigation: design of material, specificities (cycling, suction / saturation control, thermal control, etc...)
 - 10.3 field testing, field measurements
 - 10.4 available experimental results
 - 10.5 needed new developments
 - 10.6 conclusions

11 Coupled hydro - mechanical modelling of pavement materials

- 11.1 general objectives
- 11.2 general concepts
- 11.3 Finite element modelling for coupled THM problems
- 11.4 available commercial codes
- 11.5 available research codes
- 11.6 conclusions, suggestions, key aspects

12 Applications: water influence on bearing capacity and pavement performance

- 12.1 practical applications, design of pavement system, actual problem, structure design, practical rules.....
- 12.2 data for typical roads, allowing producing a full simulation : geometry, boundary conditions, material data etc...
- 12.3 geometrical data
- 12.4 boundary condition (hydraulically mainly)
- 12.5 material parameters (mechanical and hydraulic)
- 12.6 modelling results
- 12.7 frost and mechanical behaviour ; bearing capacity variation with moisture content (ice melting, heavy rains) , with temperature, with frost ; load restriction with ice melting in spring
- 12.8 analysis and conclusions
- 12.9

13 Advice on control of pavement water

- 13.1 Need for control
- 13.2 Aims in controlling groundwater
- 13.3 Current Techniques available
 - 13.3.1 Lateral drains

- 13.3.1.1 Conventional
- 13.3.1.2 Geosynthetic wrapped
- 13.3.1.3 Fin drains
- 13.3.2 Pavement underdrains
- 13.3.3 Earthwork drains
- 13.3.4 Drains beneath jointed concrete pavements
- 13.4 Novel Techniques which may become routinely available
- 13.5 Design of drainage systems
- 13.6 Appropriate use
- 13.7 Installation techniques
- 13.8 Problems experienced
- 13.9 Maintenance of drainage systems
- 13.10 Inspection of drainage systems

14 Advice on pollution mitigation

15 Mitigation and remedial methods against pollutant leaching

16 Summary, Conclusions and Recommendations

this section might be published independently

17 References

18 Glossary and List of Symbols

Appendices

(probably published separately)

- A. MOU Technical Annex
- B. COST 351 Management Committee Members
- C.