

# Water in Road Structures

ed. by Andrew R Dawson

Published by Springer, 2008

ISBN 978-1-4020-8561-1

## CONTENTS LIST

### 1 - Introduction

- 1.1. - Some History*
- 1.2. - Aims and Objectives*
- 1.3. - Organisation of Book*
- 1.4. - Pavements and Earthworks*
  - 1.4.1 - Definitions
  - 1.4.2 - Pavements and their Construction
  - 1.4.3 - A drainage classification of pavements
- 1.5. - Pavement Materials - Geotechnical Behaviour*
- 1.6. - Interaction between Percolating Water and the Pavement*
- 1.7. - Water & Alternative Materials*
- 1.8. - The Effect of Temperature*
- 1.9. - Runoff*
- 1.10. - Drainage Systems*
- 1.11. - Climate and Climate Change*
- 1.12. - Legal considerations*
  - 1.12.1 - National & Trans-national
  - 1.12.2 - Local
- 1.13. - Terminology*
- 1.14. - Conclusion*
- 1.15. - References*

### 2 - Water flow theory for saturated and unsaturated pavement material

- 2.1. - Introduction*
- 2.2. - Water balance*
- 2.3. - Relation between road and groundwater*
  - 2.3.1 - Hydrodynamic types of aquifers
- 2.4. - Porous media*
  - 2.4.1 - Grain size distribution
  - 2.4.2 - Porosity
- 2.5. - Darcy's law*
  - 2.5.1 - Factors affecting permeability
- 2.6. - Filter design*
- 2.7. - Water in the vadose zone*
  - 2.7.1 - The soil water characteristic curve (SWCC)
  - 2.7.2 - Hysteresis behaviour
  - 2.7.3 - Analytical models of the SWCC
- 2.8. - Permeability in unsaturated soil*
- 2.9. - Drainability*
- 2.10. - Conclusions*
- 2.11. - References*

### 3 - Measurement techniques for water flow

- 3.1. - Introduction*
- 3.2. - Water content*
  - 3.2.1 - Gravimetric method
  - 3.2.2 - Non-destructive methods
- 3.3. - Permeability testing*

3.3.1 - Permeability tests of saturated soils & aggregates

3.3.2 - Permeability tests of unsaturated soils

**3.4. - Suction**

3.4.1 - Tensiometers

3.4.2 - Thermal conductivity sensors

3.4.3 - Suction Plate

3.4.4 - Contact Filter Paper Techniques

**3.5. - Conclusions**

**3.6. - References**

**4 - Heat transfer in soils**

**4.1. - Introduction**

**4.2. - Basic principles of heat transfer**

4.2.1 - Conduction

4.2.2 - Radiation

4.2.3 - Vapour diffusion

4.2.4 - Convection

4.2.5 - Relative importance of the different mechanisms of heat transfer in soils

4.2.6 - Conclusions concerning heat transfer

**4.3. - Thermal conductivity,  $l$**

4.3.1 - Mineral content

4.3.2 - Porosity,  $n$

4.3.3 - Degree of water saturation,  $S_r$

4.3.4 - Temperature,  $T$

**4.4. - Thermal capacity,  $c$**

**4.5. - Thermal diffusivity,  $a$**

**4.6. - Physics of frost heave**

4.6.1 - Frost heave and Spring thaw

4.6.2 - Ice lenses

4.6.3 - Recent research

**4.7. - Conclusions**

**4.8. - References**

**5 - Water in the Pavement Surfacing**

**5.1. - Introduction**

**5.2. - Permeability of Intact Asphaltic Mixtures**

**5.3. - Permeability of Cracked Pavements**

**5.4. - Measuring Permeability**

5.4.1 - Laboratory permeability determination

5.4.2 - In-situ Infiltration Measurement

**5.5. - Water-Induced Damage in Asphaltic Wearing Surfaces**

5.5.1 - Introduction: the problem of water for road surfacings

5.5.2 - Coupled Physical-Mechanical Water-Induced Damage

5.5.3 - The Mechanical Processes Contributing to Water-Induced Damage

5.5.4 - Micro Scale Simulation of Combined Mechanical-Water Induced Damage

**5.6. - Pollution-induced degradation of bound layers**

**5.7. - Porous Asphalt**

**5.8. - Conclusions**

**5.9. - Acknowledgements**

**5.10. - References**

**6 - Sources and fate of water contaminants in roads**

**6.1. - Context**

**6.2. - Sources**

6.2.1 - Traffic and cargo

6.2.2 - Pavement and embankment materials

6.2.3 - Road equipment

6.2.4 - Maintenance and operation

6.2.5 - Snow and ice

6.2.6 - External sources

**6.3. - Flow, transport and transformation processes**

- 6.3.1 - Physical processes
- 6.3.2 - Chemical processes
- 6.3.3 - Biological processes

**6.4. - Pathways and targets**

**6.5. - European legislation**

**6.6. - Concluding remarks**

**6.7. - References**

**7 - Contaminant sampling and analysis**

**7.1. - Introduction**

**7.2. - Principles of Data Collection and Storage**

- 7.2.1 - Data Collection
- 7.2.2 - Data Storage and Retrieval

**7.3. - Sampling Design**

**7.4. - Water & Soil Sampling Procedures**

- 7.4.1 - Introduction
- 7.4.2 - Sampling of runoff
- 7.4.3 - Sampling from surface water bodies
- 7.4.4 - Sampling of Groundwater
- 7.4.5 - Sampling of soil and soil water
- 7.4.6 - Water and soil storage

**7.5. - In-situ measurements**

- 7.5.1 - Introduction
- 7.5.2 - pH
- 7.5.3 - Redox potential (in-situ)
- 7.5.4 - Electrical conductivity

**7.6. - Laboratory measurements**

- 7.6.1 - Extraction methods
- 7.6.2 - Chemical Analysis

**7.7. - Concluding remarks**

**7.8. - References**

**8 - Water influence on bearing capacity and pavement performance: field observations**

**8.1. - Introduction**

**8.2. - Pavement behaviour in relation with moisture: Water influence on bearing capacity**

- 8.2.1 - Different types of road structures versus sensitivity to water
- 8.2.2 - Pavement design and climatic effects
- 8.2.3 - Influence of water infiltration on pavement deterioration and mechanical degradation
- 8.2.4 - Water content variations in pavements
- 8.2.5 - Effect of water and loading on structure behaviour on rut progression
- 8.2.6 - Seasonal Variation of Material Parameters

**8.3. - Frost and thawing of pavements with frost susceptible soils**

- 8.3.1 - Frost heave - Introduction
- 8.3.2 - Thawing, field study, Canada
- 8.3.3 - Thawing, field study, Iceland
- 8.3.4 - Thawing and bearing capacity change, Finish example
- 8.3.5 - Monitoring Frost Depth and Thawing, Finland and Sweden

**8.4. - Conclusions, implications, recommendations**

**8.5. - References**

**9 - Water influence on mechanical behaviour of pavements: constitutive modelling**

**9.1. - Introduction**

**9.2. - Origin of mechanical properties in pavement materials**

**9.3. - General objectives, strength and deformation**

**9.4. - Models for subgrade soils and unbound granular materials**

- 9.4.1 - Resilient behaviour
- 9.4.2 - Long term elasto-plastic behaviour

**9.5. - Effective stress approach**

**9.6. - Constitutive modelling and partial saturation, suction coupling, water interaction on mechanical behaviour**

**9.7. - Conclusions**

**9.8. - References**

**10 - Water influence on mechanical behaviour of pavements: experimental investigation**

**10.1. - Introduction**

**10.2. - Laboratory investigation: cycling, suction / saturation control**

10.2.1 - Repeated load triaxial testing of unbound granular materials

10.2.2 - Control or measurement of suction / moisture

10.2.3 - Identification and estimation of model parameters

**10.3. - Bearing capacity measurements in-situ**

**10.4. - Examples of test results**

10.4.1 - Laboratory results

10.4.2 - In-situ results

**10.5. - Concluding remarks**

**10.6. - References**

**11 - Modelling coupled mechanics, moisture and heat in pavement structure**

**11.1. - Introduction – problems to be treated**

11.1.1 - Solid mechanics

11.1.2 - Diffusion

11.1.3 - Advection – diffusion

11.1.4 - Boundary conditions

**11.2. - Numerical tools : the finite element method**

11.2.1 - Introduction

11.2.2 - Finite element method

11.2.3 - Finite difference method

11.2.4 - Solving the non-linear problem – the Newton-Raphson method

11.2.5 - The stiffness matrix

11.2.6 - Transient effects : the time dimension

11.2.7 - Advection diffusion processes

**11.3. - Coupling various problems**

11.3.1 - Finite element modelling: monolithical approach

11.3.2 - Physical aspects: various terms of coupling

11.3.3 - Thermo-hydro-mechanical coupling

11.3.4 - Finite element modelling: staggered approach

**11.4. - Examples**

11.4.1 - Modelling of moisture movements (Alonso)

11.4.2 - Simulating the infiltration and percolation in a road after rainfall (Hansson)

11.4.3 - Freezing induced water flow (Hansson)

11.4.4 - Numerical simulation of pavements behaviour from accelerated tests

(Erlingsson)

11.4.5 - Example of modelling of the resilient behaviour of pavements (LCPC)

11.4.6 - Example of modelling of permanent deformations (LCPC)

11.4.7 - Example of the pollutant transport modelling in the pavement and embankment

(Apul)

**11.5. - Conclusions**

**11.6. - References**

**12 - Pollution mitigation**

**12.1. - Introduction**

**12.2. - Mitigating pollution from roads**

**12.3. - Criteria and constraints for pollution mitigation**

12.3.1 - Consideration of site sensitivity and vulnerability

12.3.2 - Risk and hazard for pollution

12.3.3 - Traffic Considerations

12.3.4 - Economic Considerations

**12.4. - Mitigation methods**

**12.5. - Conclusions**

**12.6. - References:**

**13 - Control of pavement water and pollution prevention**

**13.1. - Introduction**

**13.2. - Objectives**

**13.3. - Conception and drainage criteria**

- 13.3.1 - Road alignment and routing
- 13.3.2 - Fundamental drainage considerations
- 13.3.3 - Surface drainage system
- 13.3.4 - Subsurface drainage system
- 13.3.5 - Combined drains
- 13.3.6 - Drainage layers
- 13.3.7 - Cold climate effects
- 13.3.8 - Road runoff collection and treatment
- 13.3.9 - Filter Criteria
- 13.3.10 - The pavement as a water reservoir

**13.4. - Current techniques**

- 13.4.1 - Lateral drains
- 13.4.2 - Drainage layers for rigid pavements
- 13.4.3 - Transverse drains in rigid pavements
- 13.4.4 - Earthworks Drains
- 13.4.5 - Pavement underdrains
- 13.4.6 - Deep drains in frost-affected areas
- 13.4.7 - Dispersal and soakaways
- 13.4.8 - Road drainage and treatments systems

**13.5. - Sealing systems for environmental protection**

- 13.5.1 - Sub-soil barriers
- 13.5.2 - Surface Seals
- 13.5.3 - Examples of Seals

**13.6. - Design of drainage systems**

- 13.6.1 - Hydraulic calculation for drains ( $q_L$ )
- 13.6.2 - Drainage details

**13.7. - Construction and maintenance of drainage systems**

- 13.7.1 - Construction
- 13.7.2 - Maintenance
- 13.7.3 - Identifying rehabilitation needs

**13.8. - Future performance**

**13.9. - Conclusion**

**13.10. - References**

**ANNEX A - Seasonal variation in pavement design and analysis – some national examples**

**A1 - Introduction**

**A2 - Finland**

- A2.1 - Frost design
- A2.2 - Design to traffic / Resistance to fatigue
- A2.3 - Rutting

**A3 - USA**

**A4 - Croatia**

**A5 - Denmark**

**A6 - Sweden**

**A7 - Poland**

**A8 - References**

**ANNEX B - Terminology used for standard pavement and associated drainage items**

**D1 - Introduction**

**D2 - Highway Cross Sections**

- D2.1 - Single Carriageway
- D2.2 - Dual Carriageway

**D3 - Pavement Sections**

- D3.1 - Flexible Pavement (with verge)- Εύκαμπτο οδόστρωμα

- D3.2 - Flexible Pavement (with kerb)
- D3.3 - Permeable Pavement (SUD)-Πορώδες Οδόστρωμα

***D4 - Pavement Edge Details***

- D4.1 - Trench (“French”) Drain (Subsurface Drainage only)
- D4.2 - Trench (“French”) Drain (Surface and Subsurface Drainage)
- D4.3 - Channel Block Drainage
- D4.4 - Gully Drain
- D4.5 - Kerb And Gully Pot Drainage
- D4.6 - Swales (with Fin Drain)
- D4.7 - Ditch and Swale (with French Drain)

***D5 - Trench (“French”) and Fin Drains***

- D5.1 - Trench (“French”) Drains
- D5.2 - Fin Drain Designs
- D5.3 - Core Designs

***D6 - Water Disposal***

- D6.1 - Retention ponds
- D6.2 - Soakaways

**ANNEX C - Glossary of Words and Abbreviations**

**ANNEX D - List of Symbols**