



Statens vegvesen



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Årsaker til redusert vedheft i asfalt

Bacheloroppgave ved Institutt for Materialteknologi
NTNU

- Skrevet av Terra Varadian
- Veiledere: Kjersti Kleveland (NTNU) og Bjørn Ove Lerfald (SINTEF)

Bachelor's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Natural Sciences
Department of Materials Science and Engineering

Oterra Varadian

Examination of Adhesion between Aggregate and Bitumen in Asphalt Pavement

Comparing mineral properties of asphalt aggregates and inspecting the effects of salt in asphalt pavement.

Bachelor's thesis in Material Science & Engineering
Supervisor: Kjersti Kleveland
Co-supervisor: Bjørn Ove Lerfald
May 2024

PROBLEMSTILLING:

“Hvorfor kan to ulike steintilslag som begge møter krav for asfaltresept oppføre seg forskjellig under produksjon og i felt?”

Fokus på heft-egenskaper mellom steintilslag og bitumen.

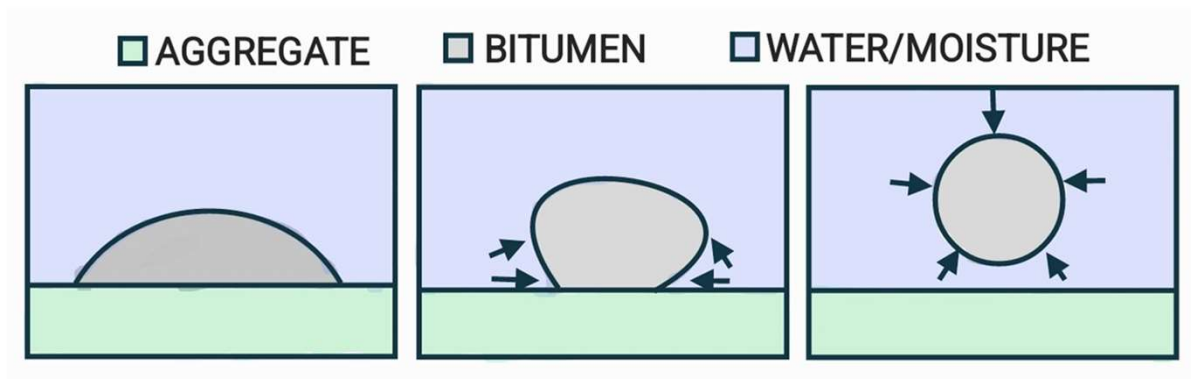


Gabbro



Syenitt

Hovedårsak til redusert heft: “Stripping”



Figuren enkelt illustrerer hydrolyse mekanismen kalt “stripping”.
Grunnet høy overflatestress og dipol-moment vil vannet kunne bryte svake heft bindinger mellom steintilslag og bitumen i asfalten.

- Medvirkende faktorer:**
- Geokjemisk komposisjon
 - Bitumen additiver
 - Tilslagets mikrostruktur
 - Termiske sykluser
 - Salt
 - Tilstrekkelig tørking av tilslag (dvelende fukt)

| Aggregate properties | Bitumen properties | Mixture properties | External factors |
|-----------------------------|---------------------------|---------------------------|-------------------------|
| Mineralogy | Rheology | Void content | Rainfall |
| Surface texture | Electrical polarity | Permeability | Humidity |
| Porosity | Constitution | Bitumen content | Water pH |
| Dust | Surface free energy | Bitumen film thickness | Presence of salts |
| Durability | | Filler type | Temperature |
| Surface area | | Aggregate grading | Temperature cycling |
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| Absorption | | | Design |
| Moisture content | | | Workmanship |
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Liste over medvirkende faktorer som påvirker heftbindinger og vedheft i asfaltmassen. Hentet fra Shell Bitumen Handbook.

- ITSR av 50 prøver kondisjonert i forskjellig konsentrasjon av saltløsning. For å se om oppløste saltioner svekker heftbindinger.
- Undersøke om dvelende fukt kan forekomme i tilslagets mikrostruktur med tynnslip-mikroskopi og elektronmikroskopi.
- Teste om våt-tørr syklus på saltløsnings-kondisjonerte prøver utgjør endring i ITSR grunnet påført stress fra salt-krystallisering i asfalt porer.

Arbeidet

58 sider, 550+ timer

- Kjemisk kvantifisering av tilslag med røntgendiffraksjon.
- Drøfting av tilslagets mineralogiske overflateladning og dens samspill med amin påvirket bitumen.
- Teste tørketid på tilslag i flere fraksjoner for å observere mulig avvik fra tørking i fabrikk.
- Videreutvikle ITSR standard med bildeanalyse-programvare for å bedre kvantifisere heftsvikt på bruddoverflate etter testing.

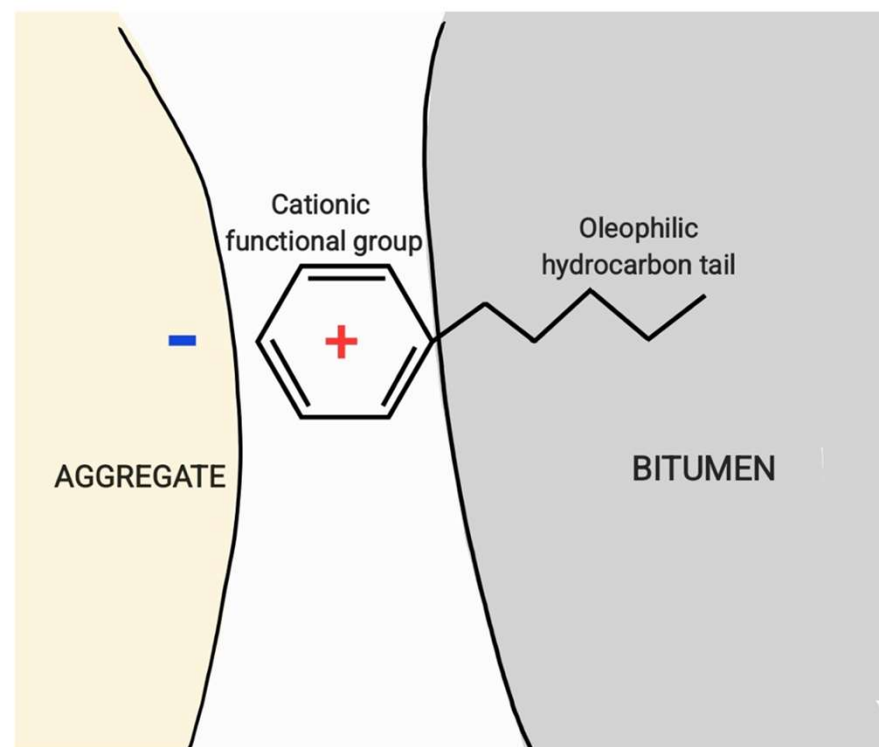
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Hva er amin-tilsetningsstoff?

Industrien går ut ifra:

- Bitumen ansees som “nøytralt-ladet”, altså ingen stor negativ eller positiv net ladning.
- Norske bergarter er “sure”, altså en net negativt ladet overflate.
- Amin-tilsetningsstoff er en kationisk emulsjon som vil gi bitumenet en positiv net ladning (WetFix).



Hvordan måle heft mellom steintilslag/bitumen og dens susceptibilitet til “stripping”?

$$n = \sqrt{\epsilon_r \mu_r}$$

Brytningsvinkel av mineraler, bitumen og vann

$$A = A_1 + A_2 = \frac{3kT}{4} \frac{\epsilon_1 - \epsilon_3}{\epsilon_1 + \epsilon_3} \frac{\epsilon_2 - \epsilon_3}{\epsilon_2 + \epsilon_3} + \frac{3h\nu}{8\sqrt{2}} \frac{(n_1^2 - n_3^2)(n_2^2 - n_3^2)}{(\sqrt{n_1^2 + n_3^2} \sqrt{n_2^2 + n_3^2})(\sqrt{n_1^2 + n_3^2} + \sqrt{n_2^2 + n_3^2})}$$

Hamaker konstant definerer kraft mellom to materialer gjennom et tredje medium.

$$W = \frac{A}{12\pi D^2}$$

Van der Waal (heft) kraft mellom stein og bitumen



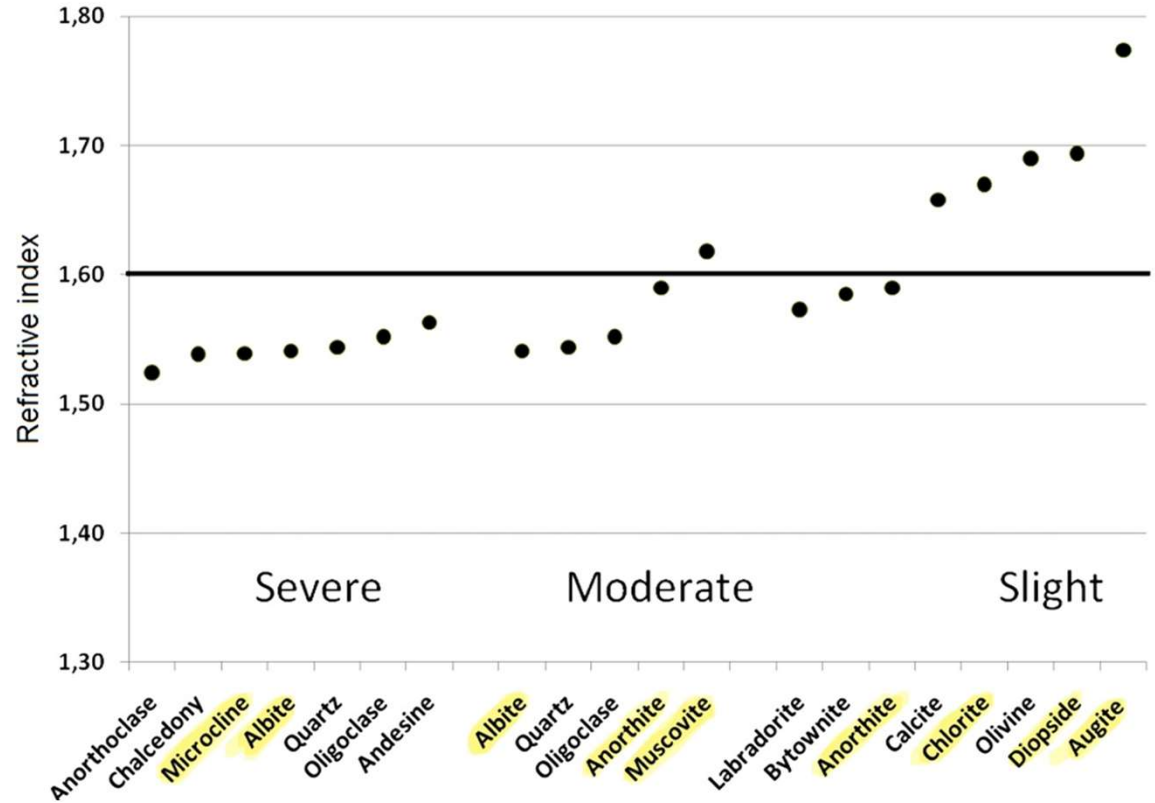
Gabbro



Syenitt

| Mineral | Gabbro | Syenite |
|--------------|--------|---------|
| Hornblende | 40-43% | 2-3% |
| Clinozoisite | 25-26% | 5% |
| Albite | 19-20% | 60-64% |
| Chlorite | 9% | - |
| Microcline | 2-3% | 16-19% |
| Magnetite | - | 4-5% |
| Muscovite | - | 2-3% |

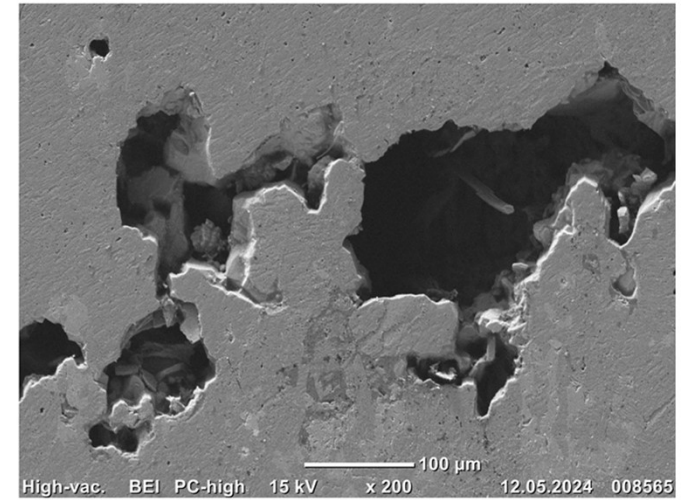
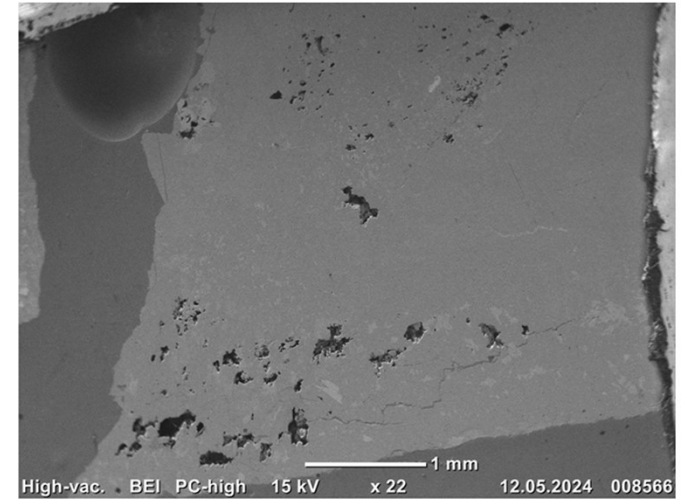
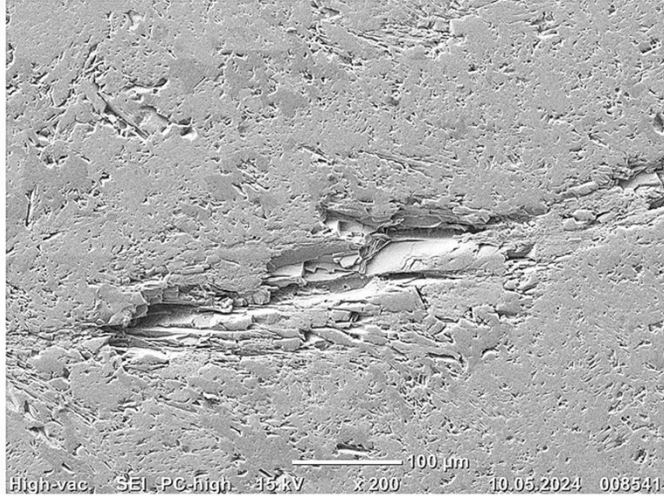
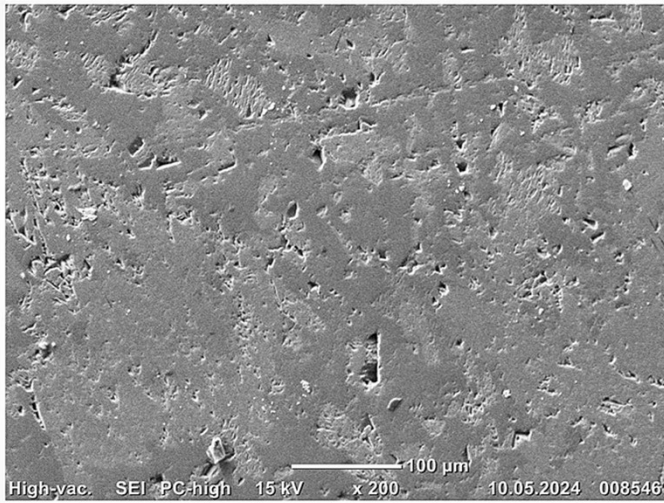
| Compounds | Gabbro | Syenite |
|--------------------------------|--------|---------|
| SiO ₂ | 48.4% | 56.2% |
| Al ₂ O ₃ | 14.9% | 19.5% |
| CaO | 11.8% | 4.76% |
| Fe ₂ O ₃ | 9.68% | 5.29% |
| Na ₂ O | 2.79% | 5.86% |
| MgO | 8.24% | 1.22% |
| K ₂ O | 0.06% | 3.59% |
| LOI | 0.91% | 2.55% |



PhD Åsa L. Lyne (KTH) klarte å skape en korrelasjon mellom mineral brytningsvinkel og susceptibilitet til "stripping" (heftsvikt).

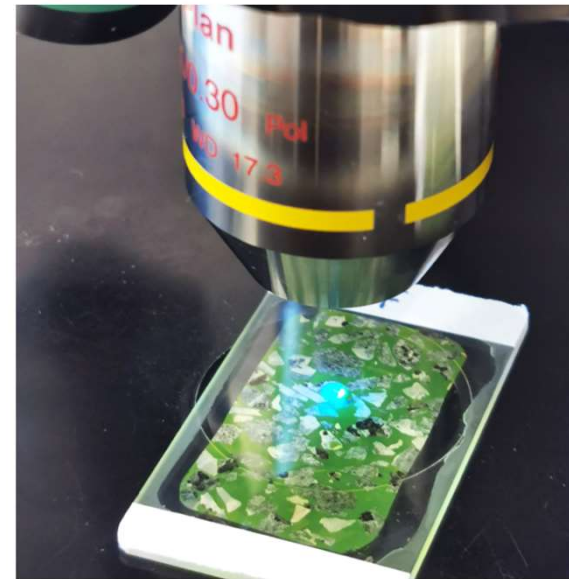
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Liste over medvirkende faktorer som påvirker heftbindinger og vedheft i asfaltmassen. Hentet fra Shell Bitumen Handbook.



Gabbro
ru overflate og lav forekomst av porer.

Syenitt
"glatt" overflate og høy forekomst av porer.



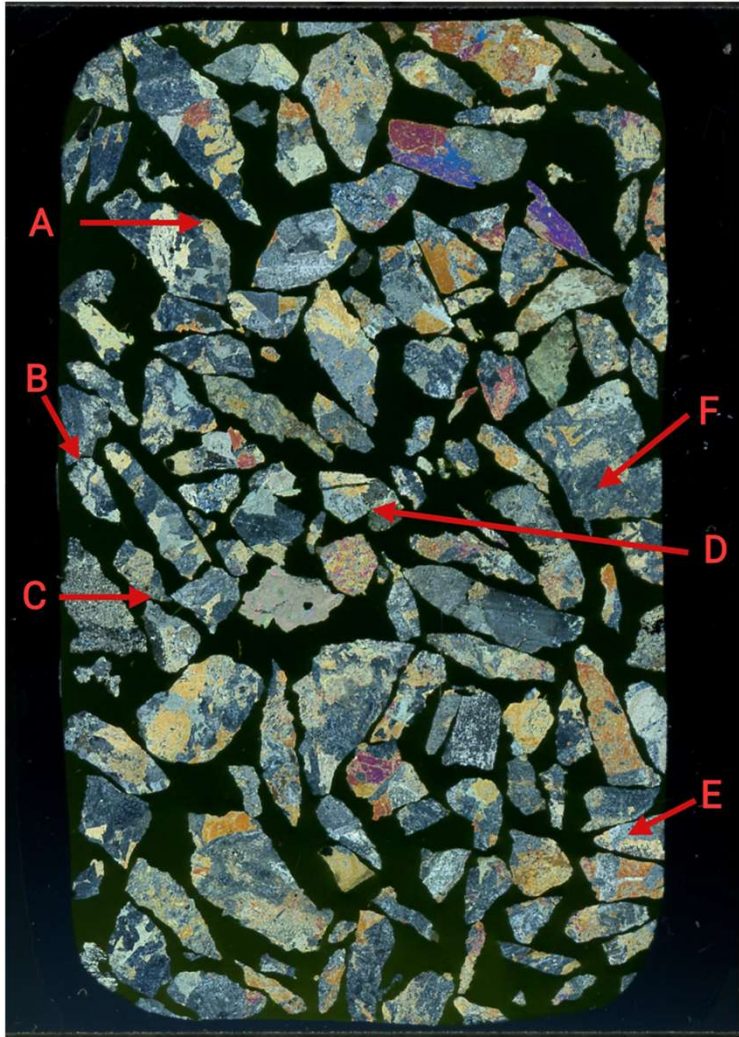


Figure 4.2: Photo-scan of gabbro thin section with overview of observed micro-cracks shown in Fig 4.3.

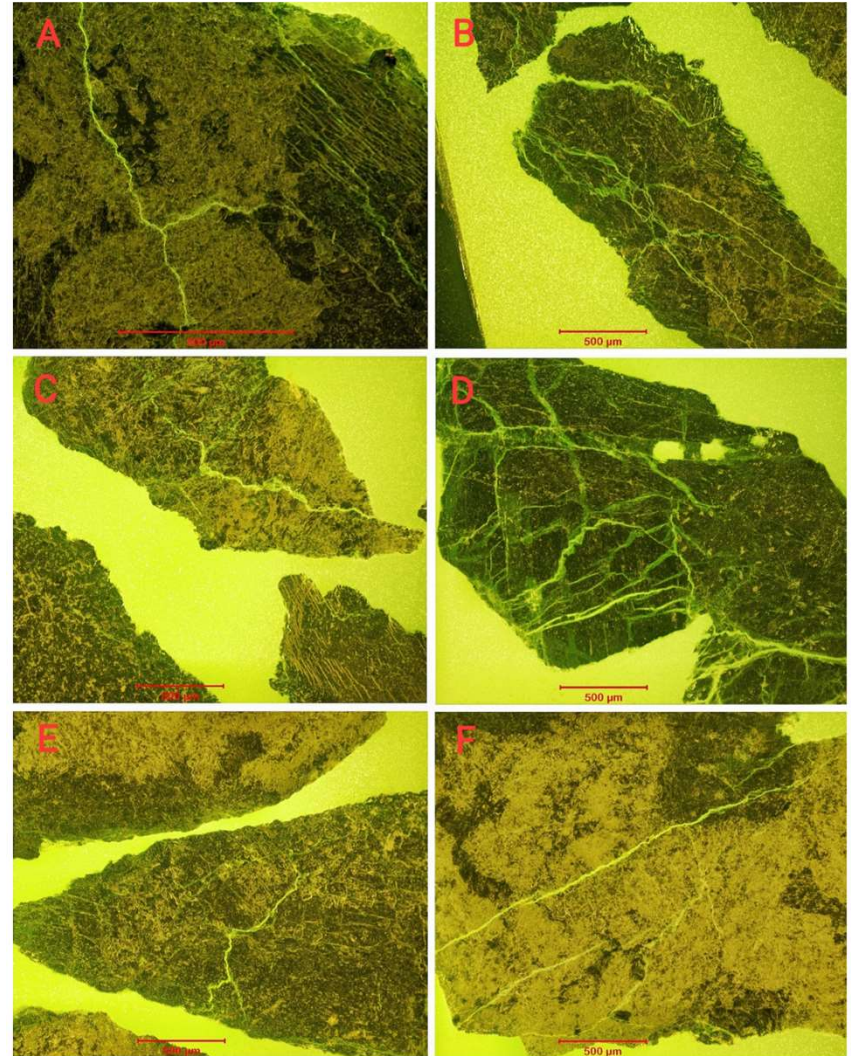


Figure 4.3: Observed occurrences of micro-cracks in gabbro thin section

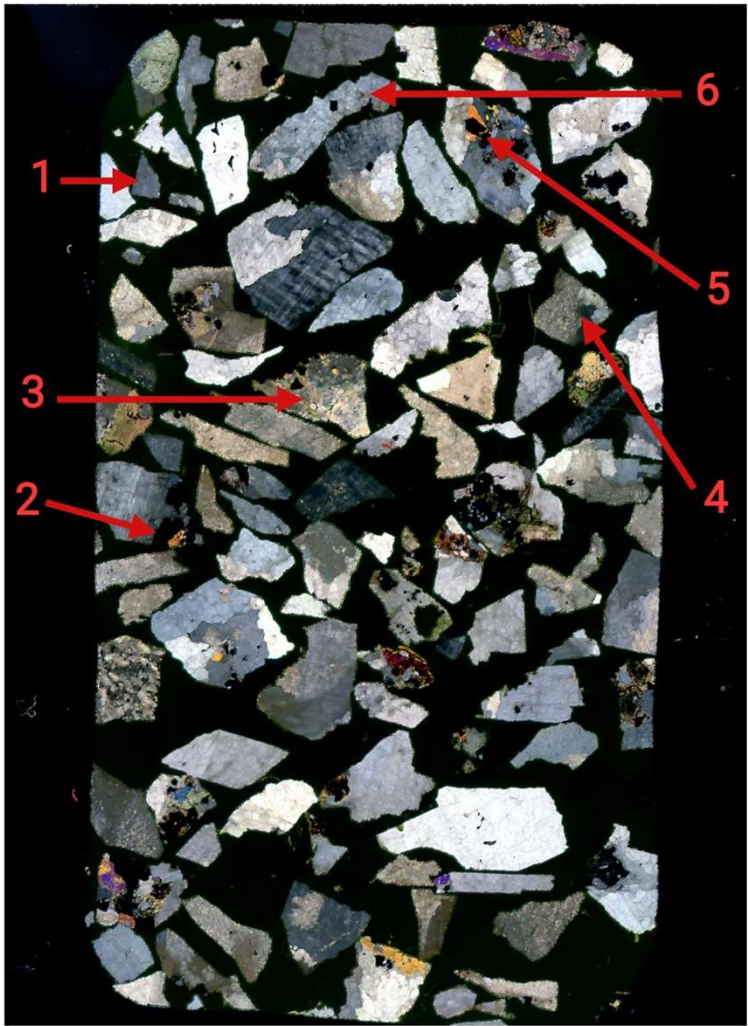


Figure 4.4: Photo-scan of feldspar aggregate thin section with overview of observed micro-cracks shown in Fig 4.5.

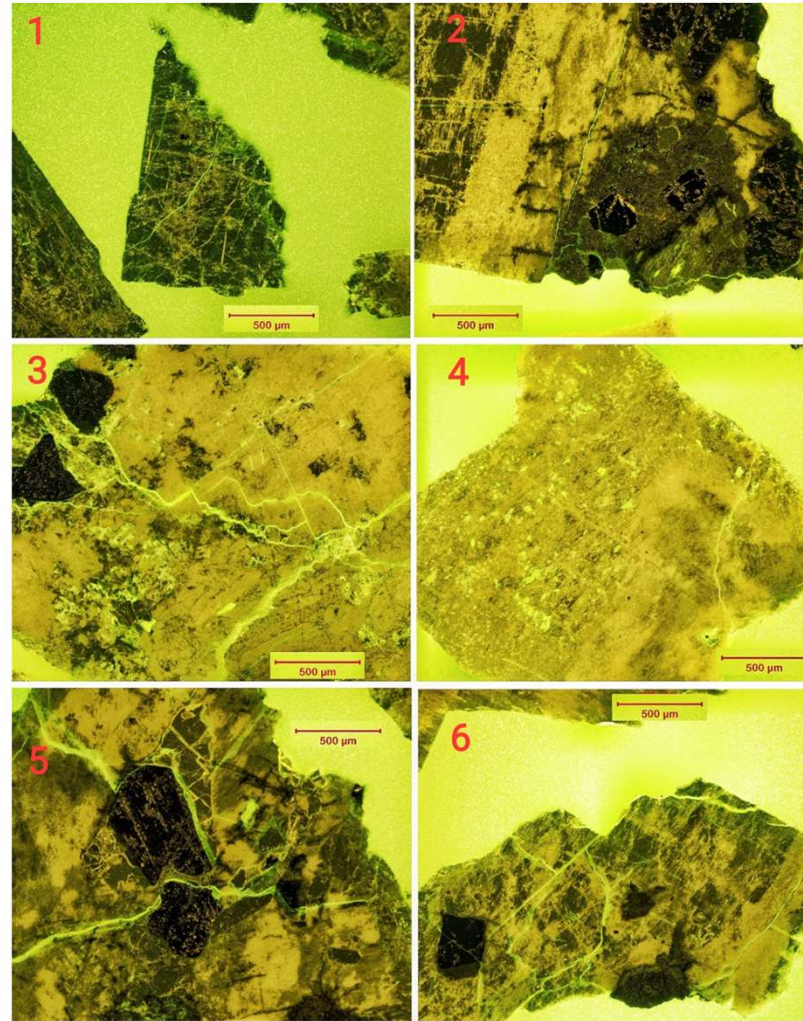


Figure 4.5: Observed occurrences of micro-cracks in feldspar aggregate thin section. A trend of micro-crack propagation appears along grain boundaries of magnetite (dark mineral) in 2,3,5 and 6.

| Aggregate properties | Bitumen properties | Mixture properties | External factors |
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Figure 3.6: The asphalt sample in the ITS machine (left), producing two fracture surfaces (middle) and corresponding compression graph of 4 samples (right).

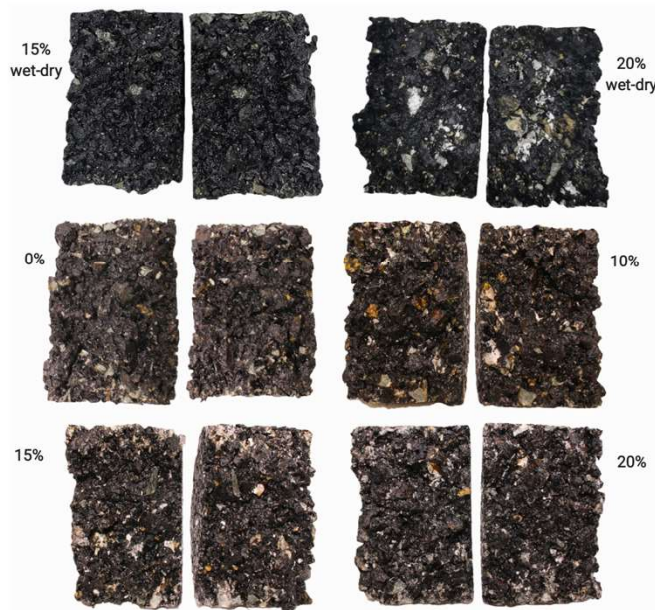


Figure D.1: Photos of ITS fracture surfaces for salt conditioned gabbro samples

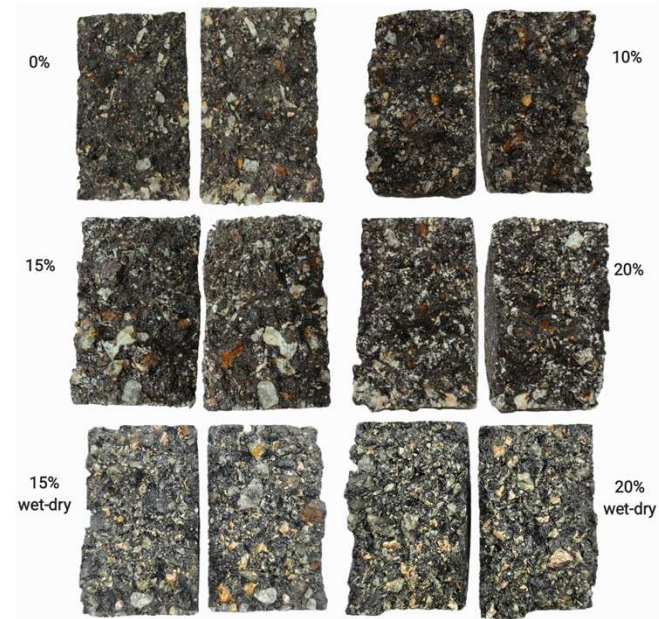


Figure D.2: Photos of ITS fracture surfaces for salt conditioned feldspar samples

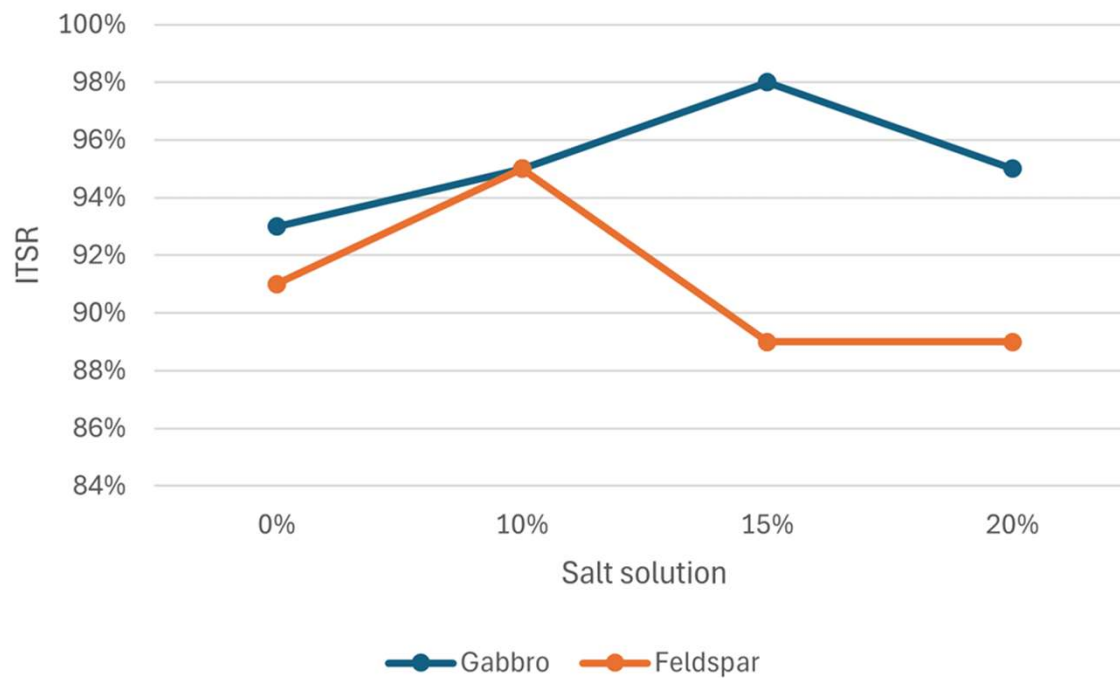


Figure 4.9: Diagram of ITSR of both aggregate mixtures for each salt solution. Values found in Tab. 4.5.

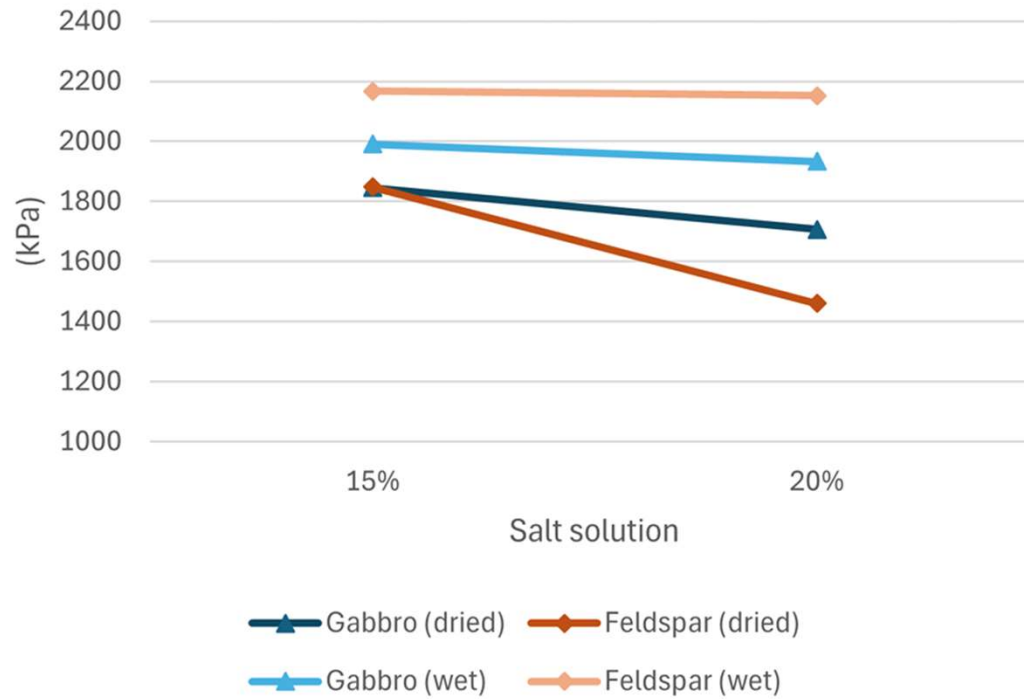


Figure 4.10: Diagram of ITS results for salt conditioned samples after drying compared to wet/saturated salt conditioned samples (wet-dry cycle).

Summa summarum

| | Gabbro | Syenite (Feldspar) |
|---|---|--|
| Mineralogy (XRD & XRF) | Average refractive index above 1.6. | Average refractive index below 1.6. |
| | Basic (45-52% SiO ₂). | Intermediate (52-63% SiO ₂). |
| | Higher alkaline earth metal content (Ca & Mg). | Higher alkali metal content (Na & K). |
| | Lower water retention and drying time. | Higher water retention and drying time. |
| Micro-structure (SEM) polished cross-section | Low occurrence of micro-cracks | Severe occurrence of micro-cracks |
| | Moderate porosity | Severe porosity |
| | Severe surface roughness | Low surface roughness |
| Micro-cracks (thin section) | Below moderate occurrence of micro-cracks. | Below moderate occurrence of micro-cracks. |
| | No visible trend in crack propagation. | Higher occurrence of crack propagation along magnetite grain boundaries. |
| Presence of salts (ITSR, ITS & wet-dry) | Moderate increase in ITSR with salt. | Moderate decrease in ITSR with salt. |
| | Moderate decrease in ITS with salt wet-dry cycle. | Severe decrease in ITS with salt wet-dry cycle. |
| | Visible salt deposits on fracture surfaces. | No visible salt deposits on fracture surfaces. |



Statens vegvesen

Takk for meg :)

Bare å ta kontakt <3

