Density measurements of road overlays samples with nuclear gauges and a Step Frequency Radar

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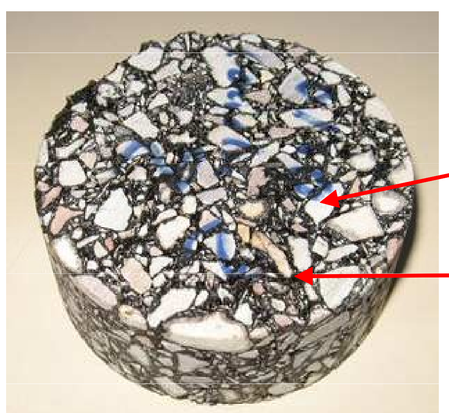
1. Studied Media



Hot Mix Asphalt layers = porous media (C the volume concentration) with :

- Aggregates and fines, C_a+C_f ~[88 to 96%]:
- Bitumen, C_b ~[4 to 7%];
- Air, C_{air} ~[4 to 12%]

Compaction C

$C = C_a+C_f+C_b = 1-C_{air}$

HMA and real density

$\rho_{HMA} = C\rho_{real}$

HMA Permittivity (CRIM Model)

$\varepsilon_{HMA}^{\alpha} = C_a\varepsilon_a^{\alpha} + C_b\varepsilon_b^{\alpha} + C_f\varepsilon_f^{\alpha} + C_{air}\varepsilon_{air}^{\alpha}$

$\alpha \in [-1;1]$

Relation between compaction, HMA permittivity and density

$\rho_{HMA} = f(\varepsilon_i, C_i)\rho_{real}$

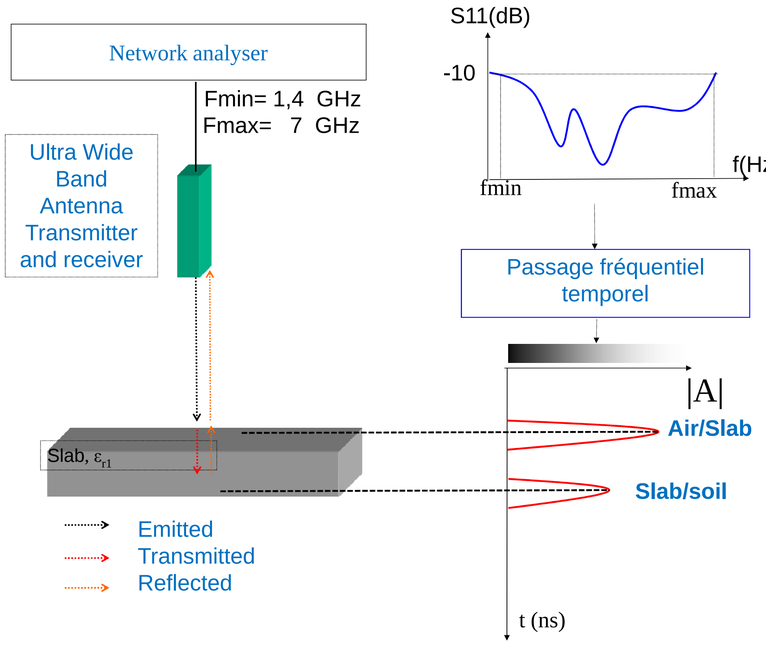
ε_{HMA} measured by SFR method

ε_a, ε_b, ε_f, ε_{air}, known

$\alpha \in [-1;1]$

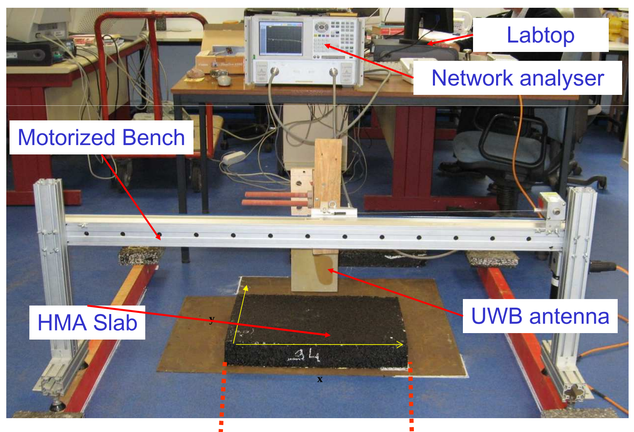
2. Step Frequency radar

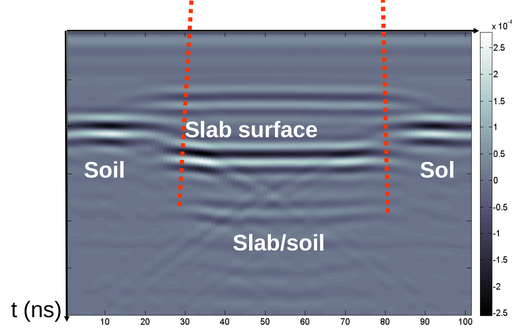
Principle



Result

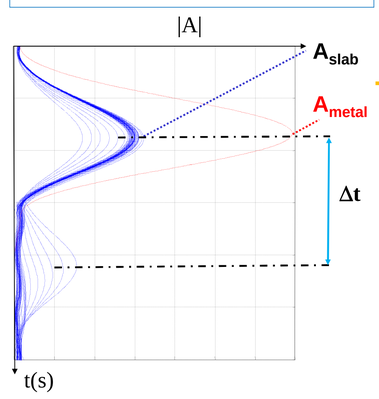
Passage fréquentiel temporel





Bscan example with SFR method, D(cm)

Slab permittivity



$R = \frac{A_{slab}}{A_{metal}}$

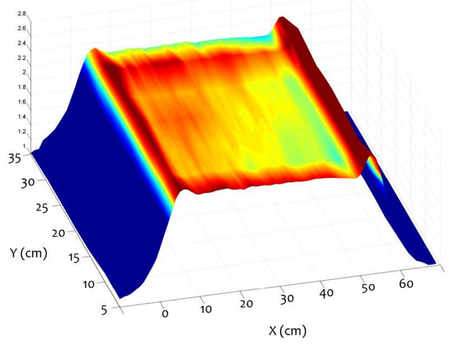
1) Surface permittivity

$\varepsilon'_{r,surf} = \left(\frac{1+R}{1-R}\right)^2$

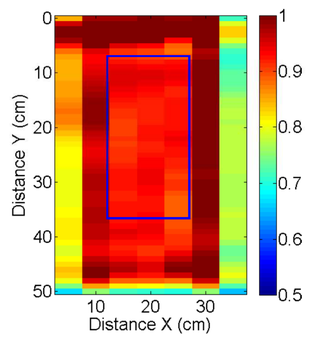
2) Volume permittivity

$\varepsilon'_{r,volume} = \left(\frac{c}{2e}\times\Delta t\right)^2$

3D permittivity

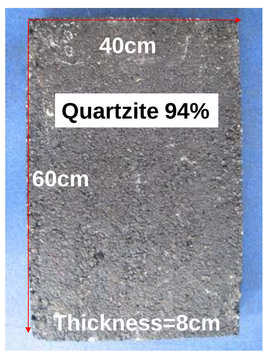


SFR Map compaction



3. Comparison of SFR and nuclear gauge density

Tested HMA materials: 3 types of slabs implemented at different compaction level

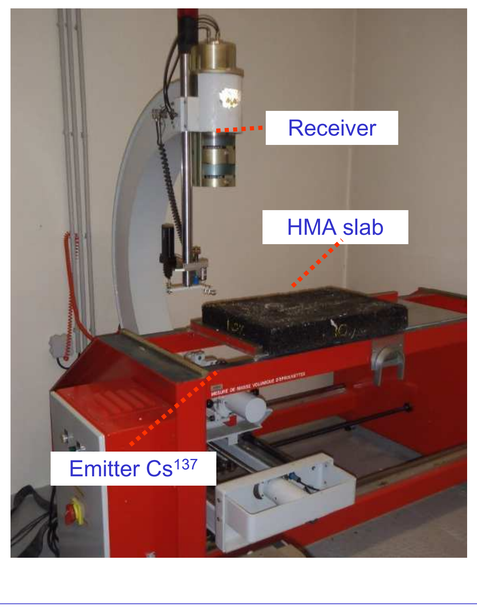


1 – Quartzite (99%)
2 – Fine (1%)
3 – Bitume ext (4,7%)
4 – ρ_{real}=2,475 g/cm^3

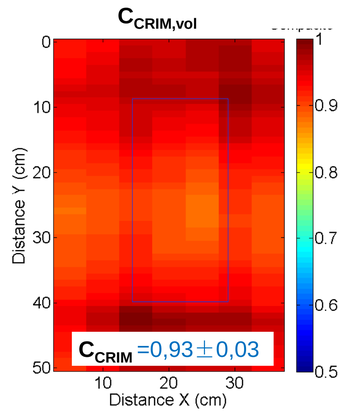
1 – Basalte (93%)
2 – Fine (1,7%)
3 – Bitumen int (5,3%)
4 – ρ_r=2,680 g/cm^3

1 – Chalk(100%)
2 – fine (0%)
3 – Bitumen ext (4,7%)
4 – ρ_r=2,486 g/cm^3

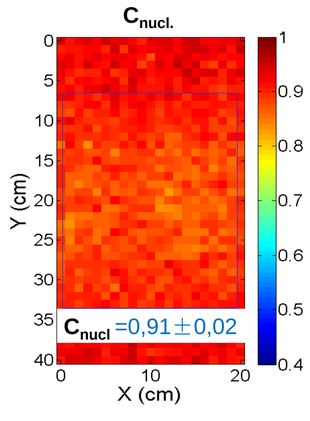
Gamma bench (NF-EN 98250.5): reference method for SFR comparison



SFR Volume map compaction: the considered compaction is averaged



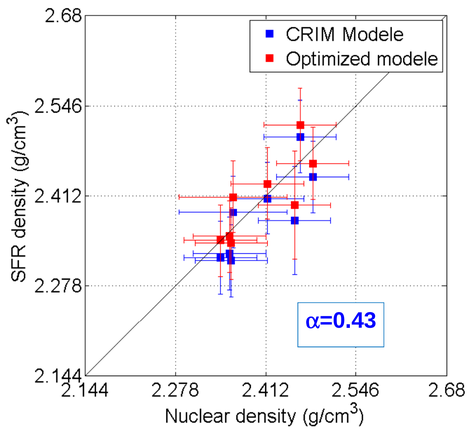
Nuclear map compaction obtained witjh gamma bench



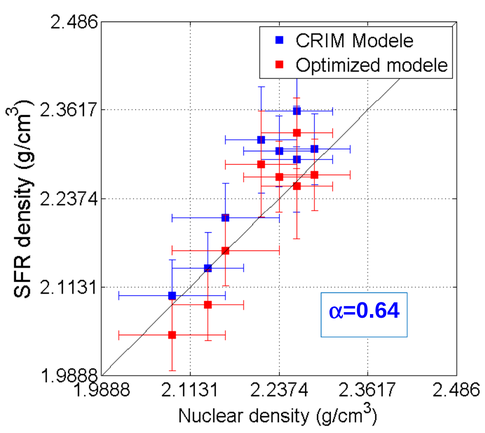
$\rho_{HMA} = C\rho_{real}$

Density estimated by averaged map compaction C and real HMA density
1 – In blue, with α=0.5
2 – In red, with optimized α

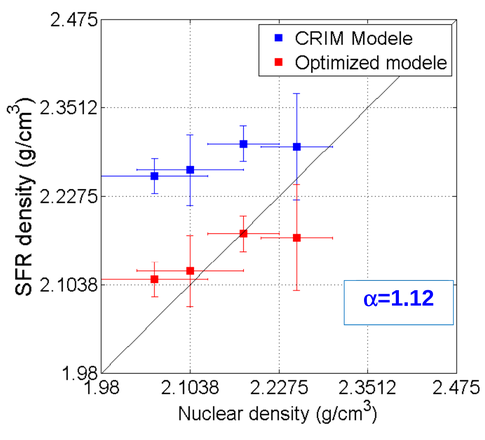
HMA basalt density (8 slabs)



HMA chalk density (8 slabs)



HMA quartzite density (4 slabs)



Density estimation by SFR method are closed to density estimated by nuclear method

1 – 3% for HMA quartzite slabs,
2- less than 2% for basalt and chalk slabs

References:

Fauchard C., Li B., Mazari B., "Estimation of compaction of bituminous mixtures at microwave frequencies", NDTCE'09, Nantes, France, Juillet 2009

Fauchard C., Rejiba F., Derobert X. and Côte Ph. (2008), "Step frequency radar applied to asphalt thickness measurements with various interface conditions", *12th International Conference on Ground Penetrating Radar* 15-19 June 2008

NF EN 12 697-7 : Mélanges bitumineux – Méthodes d'essai pour mélange hydrocarboné à chaud – Partie 7 : détermination de la masse volumique apparente des éprouvettes bitumineuses par les rayons gamma