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Solutions for Low Noise Road Surfaces - Solutions/success stories from EU-funded projects -WEBINAR- 6 FEBRUARY 2024

Panel 1 discussion: Technical challenges of low noise asphalt mixture production. 11:30 – 12:30

Outline

1.Many concurring instances

2.Design and production of low-noise surfaces

3.Noise vs. texture

4.Noise vs. friction

5.Noise vs. rolling resistance

6.Solutions

7.References

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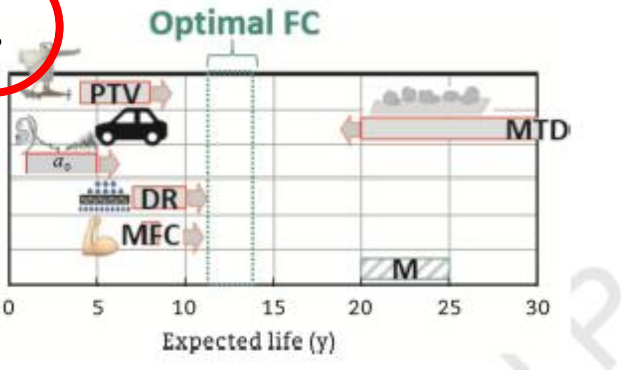

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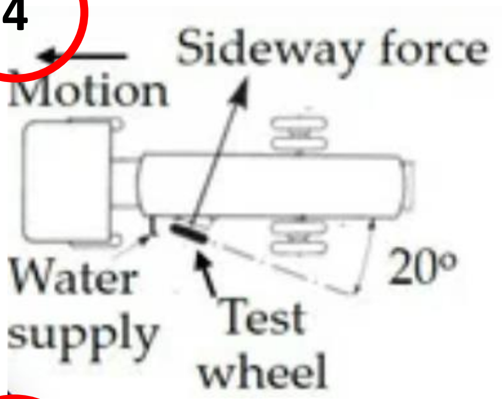

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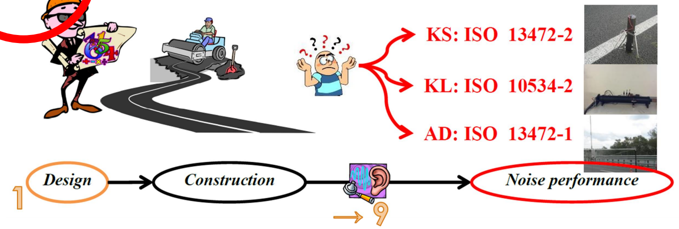

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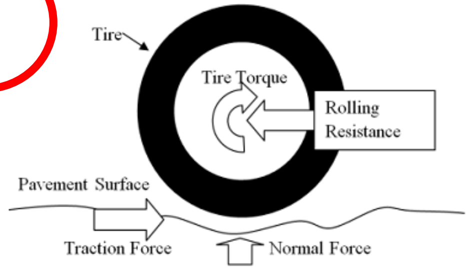

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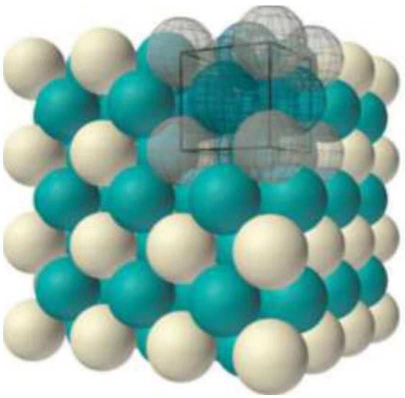

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Part 1-Many concurring instances (Problem statement)

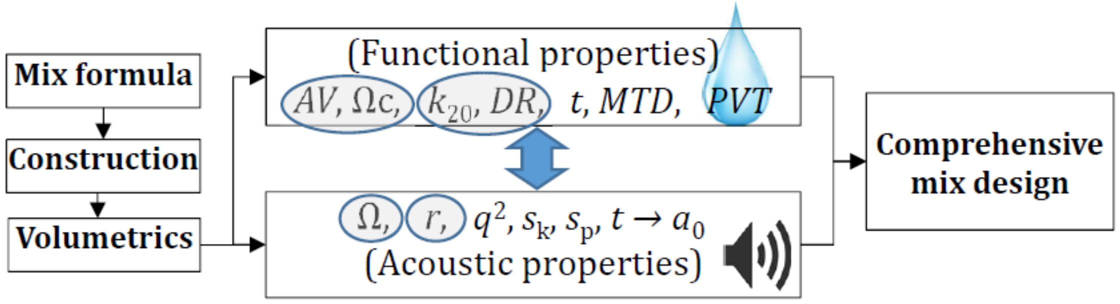
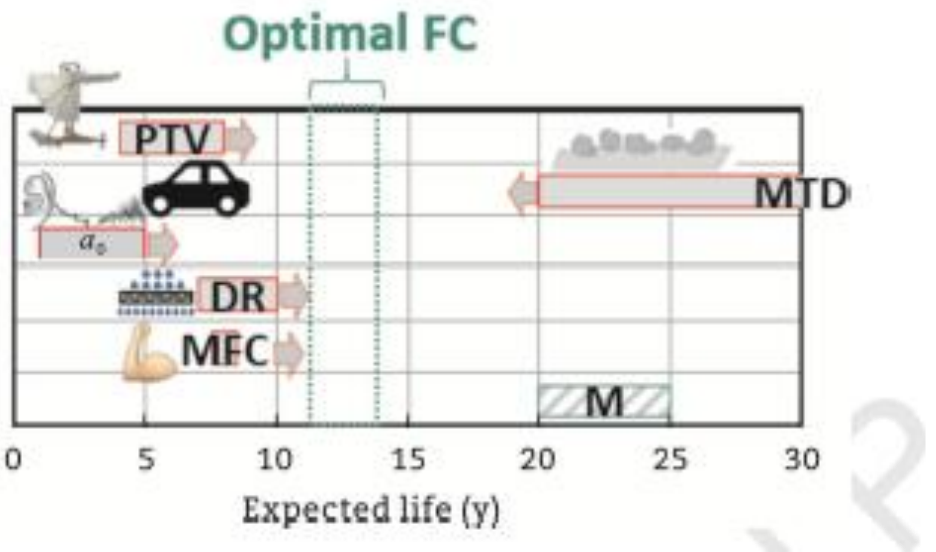


Figure 1. Summary of the study



Concurring parameters and needs

- Friction (safety) $\mu = \frac{F}{Fw}$
- Texture (safety) MPD
- Mechanistic properties (economy) MI
- Rolling resistance (economy/sustainabili

$$F = C_{rr} N$$

$$F_r = m_1 \times g \times (0.00912 + 0.0000210 \times \mathrm{IRI} \times v + 0.00172 \times \mathrm{MPD})$$

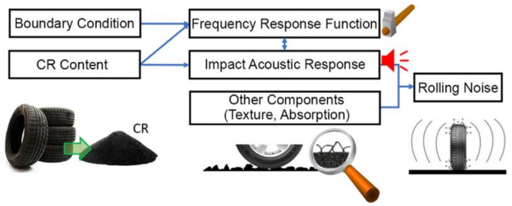
- Noise (sustainability/health)

$$p_u = \frac{A_d}{r_d} \cdot e^{i \cdot k_d \cdot r_d} + \frac{A_r}{r_r} \cdot Q_u \cdot e^{i \cdot k_r \cdot r_r}$$

Acoustical pressure (Ad, Ar: generation factors; rd, rr: geometry; kd, kr: wave numbers; Qu: spherical reflection coefficient).
F: is the rolling resistance force Crr: is the dimensionless rolling resistance coefficient or coefficient of rolling friction (CRF), N=W=is the normal force, the force perpendicular to the surface on which the wheel is rolling.

Part 2- Design and production of low-noise surfaces

- Vibrations and acoustics
- Known solutions
- Tailored solutions: principles behind and algorithms to effectively design (absorption, texture, other effects cf. Pavement FRFs and noise: A theoretical and experimental investigation)
- “Noise vs. materials”
- Noise vs. asphalt plant issues



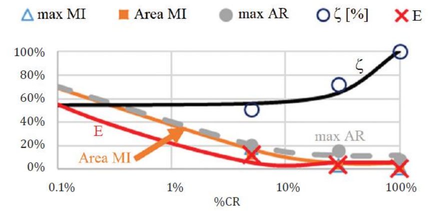


Figure 2. CR impact on noise (AR) and mechanistic response (MI, ζ, and *E*) elaborated from (Praticò et al., 2021b, 2021a)

Low-noise pavements	Propagation	Impacts			
Rolling noise		Acoustics	Psychoacoustics	Music	Woman /man real perception
Tyre and pavement	Pavement, Barriers, wind….	ISO statistical pass-by SPB method (ISO 11819-1); ISO Close ProXimity CPX method (ISO11819-2); acoustic absorption; …	Loudness (.. Volume, ISO 532-1; Sharpness (DIN 45692- amount of high-frequency components in a sound); Roughness (fast amplitude modulations, cf. Sottek); Fluctuation strength (describes modulation frequencies below 20 Hz., cf. Sottek modified)*	Pitch (altezza-frequenza); Duration (durata); Loudness (volume forte o piano); Timbre (Timbro-forma onda Sonora-spettro armónico-clarinetto-oboe); Texture (tempo, battute per minuto,..)	

*Lo Castro et al, 2018 The LIFE NEREiDE project: psychoacoustic parameters and annoyance of road traffic noise in an urban area

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Designing to mitigate vibrations and noise

complex scenarios

vibrations

Noise

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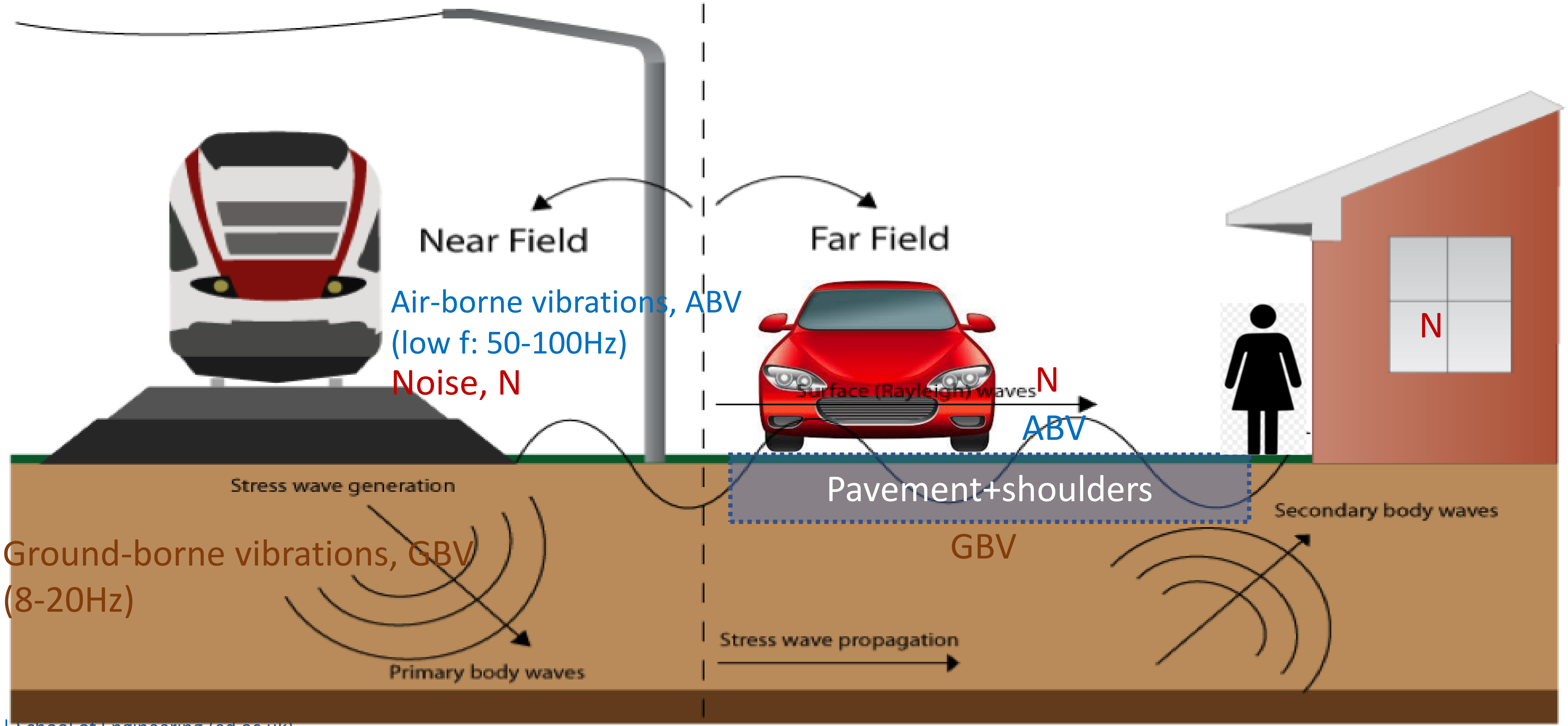
Complex scenarios



Adapted from [Railway Engineering | School of Engineering (ed.ac.uk)]

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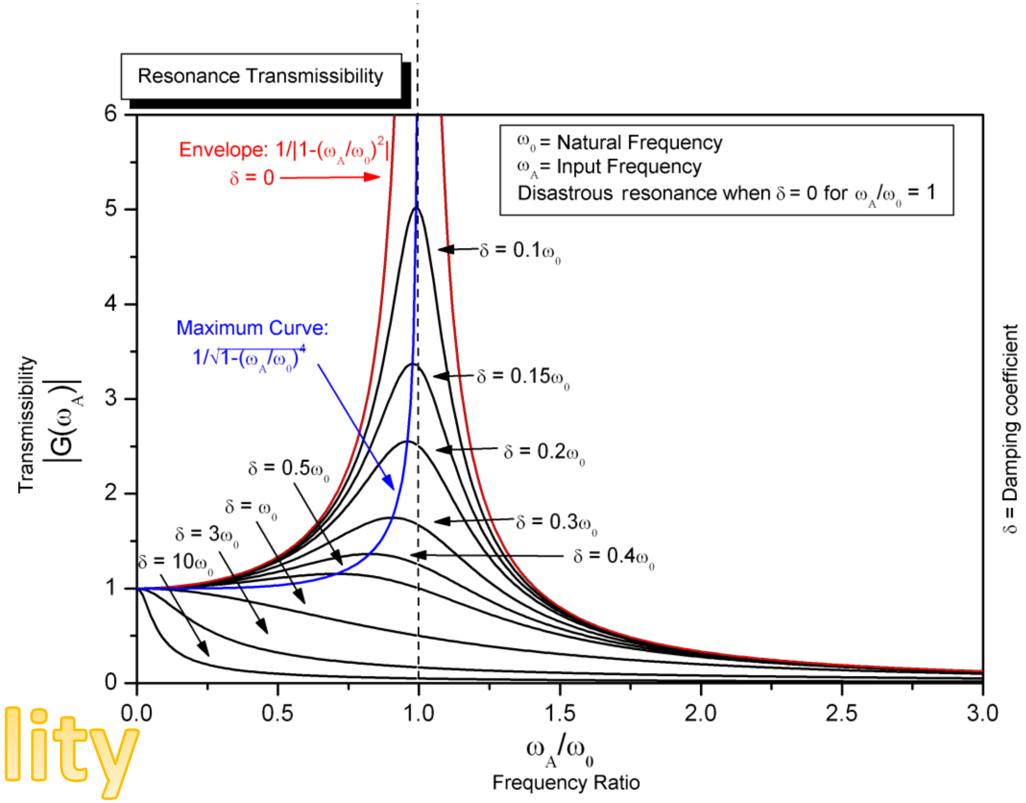
Mitigating vibrations

A simplified approach



Frequenze-frequencies
Smorzamento-damping
Trasmissione-transmissibility

By "MasterHD" / MasterHD at English Wikipedia - "User:amueckl", Public Domain, https://commons.wikimedia.org/w/index.php?curid=4970356

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Track excitation in relation to frequency (adapted from Esveld, 2001)

wavelength										
		0.3m		3m		10m			120m	
Hertzian spring	Welds		Wheels 20-100Hz		Bogie 5-20Hz		Sprung mass 0.7-5Hz			
			Rolling defects				Ballast and formation			

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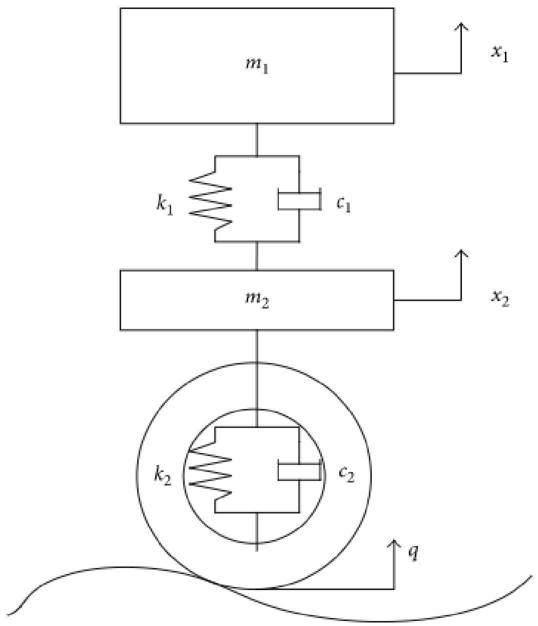
Pavement excitation



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https://www.hindawi.com/journals/ace/2018/2714657/

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Mitigating vibrations

	Generation	Propagation	Receiver -Effects and generation
	Ground-borne (low f: 8-20Hz)	Pavement-geological strata	Building foundations and floors
	Air-borne	Air propagation	Building, front rooms, windows, doors
Mitigation class	Vehicle (tyre); rolling stock (bogie suspensions, brakes, wheels), Railtrack (rails), pavement (composition, geometry, damping layers), infrastructure overall design	Track (pads, slabs, rails), pavement (roughness), transmission path (trenches, embankment), Geometry, Tanks, trench barriers, wave barriers	Base isolation, walls, doors, windows

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Designing quiete asphalt concretes

- **Adopting known solutions**

- **2. Designing**
  - 2.A Multi-purpose design (Overall design)
  - 2.B Noise-oriented design (A) Texture-based; B) acoustic absorption-based; C) Modulus-MI-based.

1. References for adopting known solutions

- Sandberg U., and Ejsmont J., Tyre/road noise. Reference book, INFORMEX.

- Praticò, F.G., Swanlund, M., George, L-A., Anfosso, F., Tremblay, G., Tellez, R., KAMIYA, K., Del Cerro, J., Van der Zwan, J., Dimitri, G.(2013). Quiet pavement technologies, Pages : 105, PIARC Ref. : 2013R10EN, ISBN : 978-2-84060-327-6.

- Lodico D., Donavan, P., CTHWANP-RT-18-365.01.1, Quieter Pavement: Acoustic Measurement and Performance, February 2018

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1. References for adopting known solutions

Reference	Type of solutions	Thickness (mm)	Nominal Maximum Aggregate size or NMAS (mm)	Texture (mm) or/and air void content (%)	Acoustic indicator used	Noise reduction (dB)	Noise increase (dB/year)
(Donavan and Janello, 2018)	ARFC	25 mm	9.5 mm	20-21%	CPX/OBSI	/	0.5 dB/Year
(Anderson et al., 2013; Pierce et al., 2009)	OGFC-AR	19 mm	9.51 mm		OBSI	4.3 (vs. HMA)	2.1
	OGFC-SBS	19 mm	9.51 mm		OBSI	3.4 (vs. HMA)	1.45
	HMA	30 mm	12.5 mm		OBSI	/	1.03
(Bendtsen et al., 2010, 2009; Illingworth et Rodkin, 2002)	OGAC	25 mm	9.5 mm	/	/	/	0.11-0.19
(Bendtsen et al., 2010, 2009; Rochat et al., 2010)	DGAC	30 mm	12.5 mm	9%	SPB	/	0.24*-0.29**
	OGAC	30 mm	12.5 mm	15%	SPB	1.7 (vs. DGAC)	0.20*-0.12**
	OGAC	75 mm	12.5 mm	12%	SPB	3.3 (vs. DGAC)	0.10*-0.31**
	RAC-O	30 mm	12.5 mm	12%	SPB	2.3 (vs. DGAC)	0.40*-0.36**
	BWC	30 mm	12.5 mm	7%	SPB	0.9 (vs. DGAC)	/
(Bendtsen and Nielsen, 2008)	DGAC11	33 mm	11	2.8	SPB/CPX	/	0.72*-0.8**
	UTLAC	22 mm	8	14.4	SPB/CPX	2.2 (vs. DGAC11)	1.06*-0.35**
	OGAC	28 mm	8	15.3	SPB/CPX	2.9 (vs. DGAC11)	0.8*-0.09**
	SMA8	29 mm	8	12.4	SPB/CPX	0.4 (vs. DGAC11)	0.5*-0.21**
	SMA6+	26 mm	6+5/8	3.0	SPB/CPX	1.6 (vs. DGAC11)	0.93*-0.63**
	SMA8+	33 mm	8+8/11	5.7	SPB/CPX	2.5 (vs. DGAC11)	1.32*-0.67**

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2. Tailored and/or innovative solutions: balancing

<table>
<tr><th>Domain of interest</th><th>Main volumetrics</th><th>Main impacts</th></tr>
<tr><td>Grading of aggregates/CR</td><td rowspan="7">Gb, Gmb, Gmm,
Gsb, Gsa, Pb, Pba,
AV, Ω=neff,
VMA, VFA, DP

LTx
q^2, Rs, $s\rho$, $s\kappa$, Λ, Λ', k_0'
Optical properties
….</td><td rowspan="7">Functional properties (acoustics, friction, texture, ….).
Mechanistic (……) and durability (PD, TC, F; abrasion, PM).
«high-level»?(LCA, LCC, costs)
…..</td></tr>
<tr><td>Aggregate/CR/other materials mineralogy, angularity, and remaining characteristics</td></tr>
<tr><td>Quality/grade/percentage of bitumen</td></tr>
<tr><td>Quality and quantity of the remaining materials</td></tr>
<tr><td>Compaction</td></tr>
<tr><td>Thickness</td></tr>
<tr><td>Temperatures (transport, lay down, compaction)</td></tr>
<tr><td>….</td><td></td><td></td></tr>
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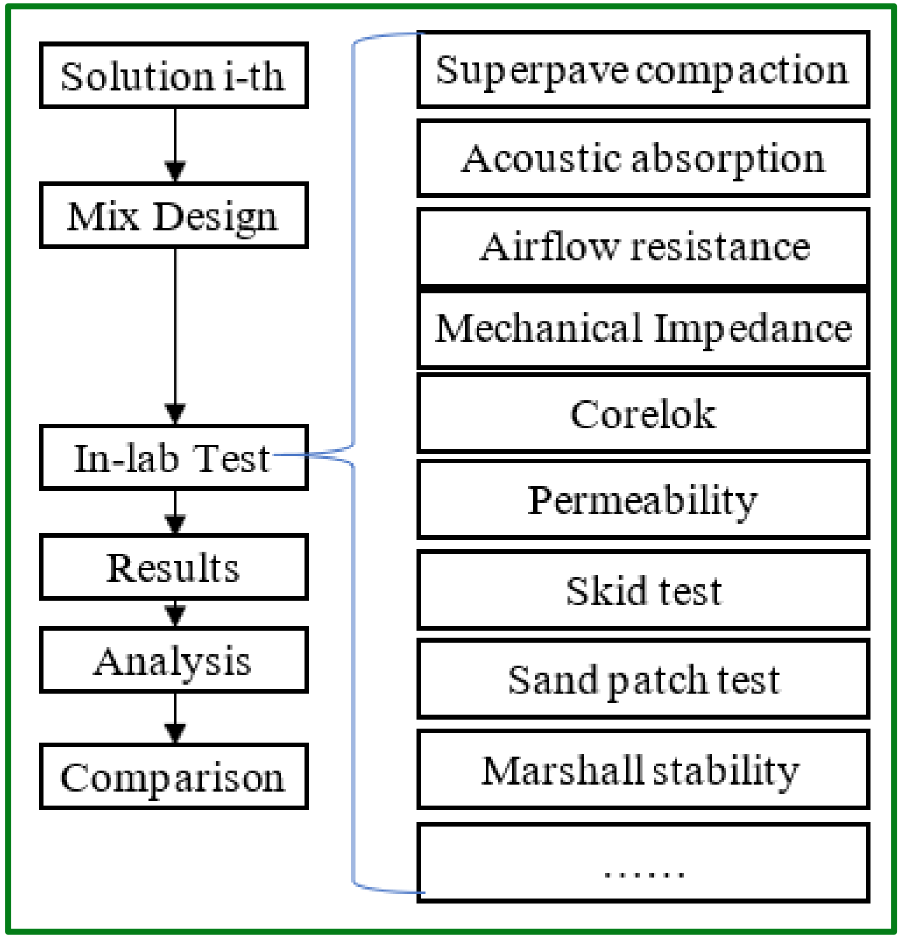
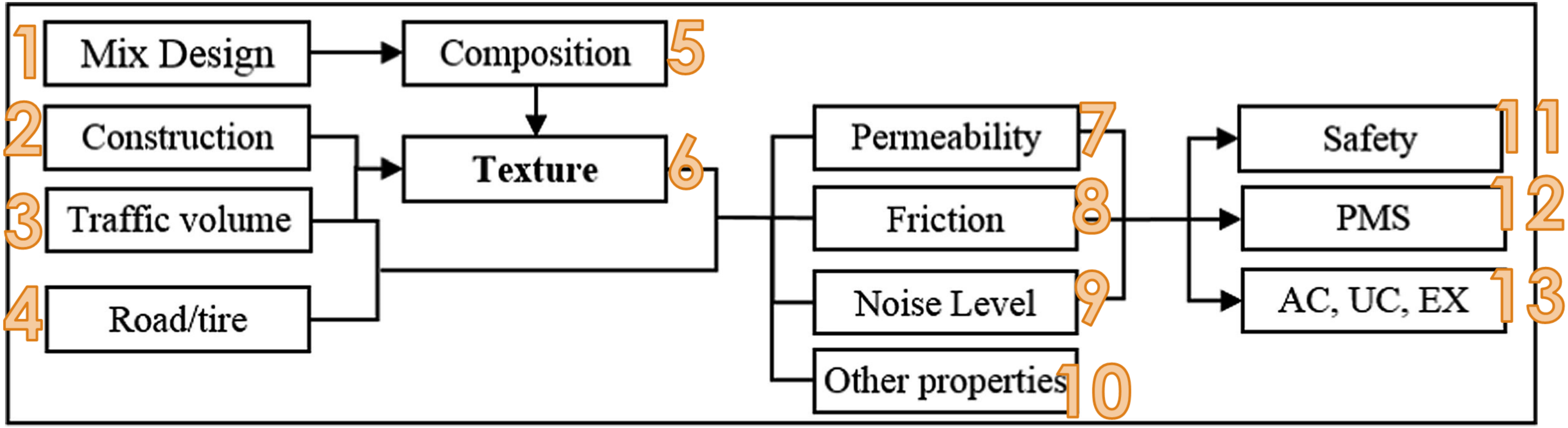
2.1 The essence of design…



Plan of experiments

2.2 Noise-oriented design of a pavement mixture



F.G. Praticò, P.G. Briante, Prediction of surface texture for better performance of friction courses, Construction and Building Materials, Volume 230, 2020, 116991, ISSN 0950-0618, https://doi.org/10.1016/j.conbuildmat.2019.116991.

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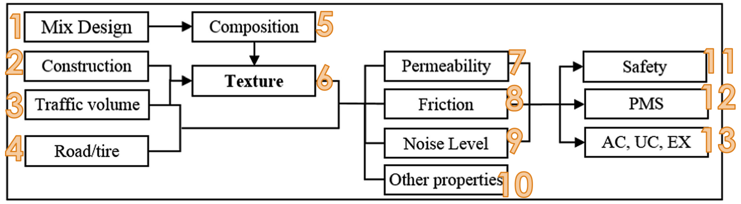
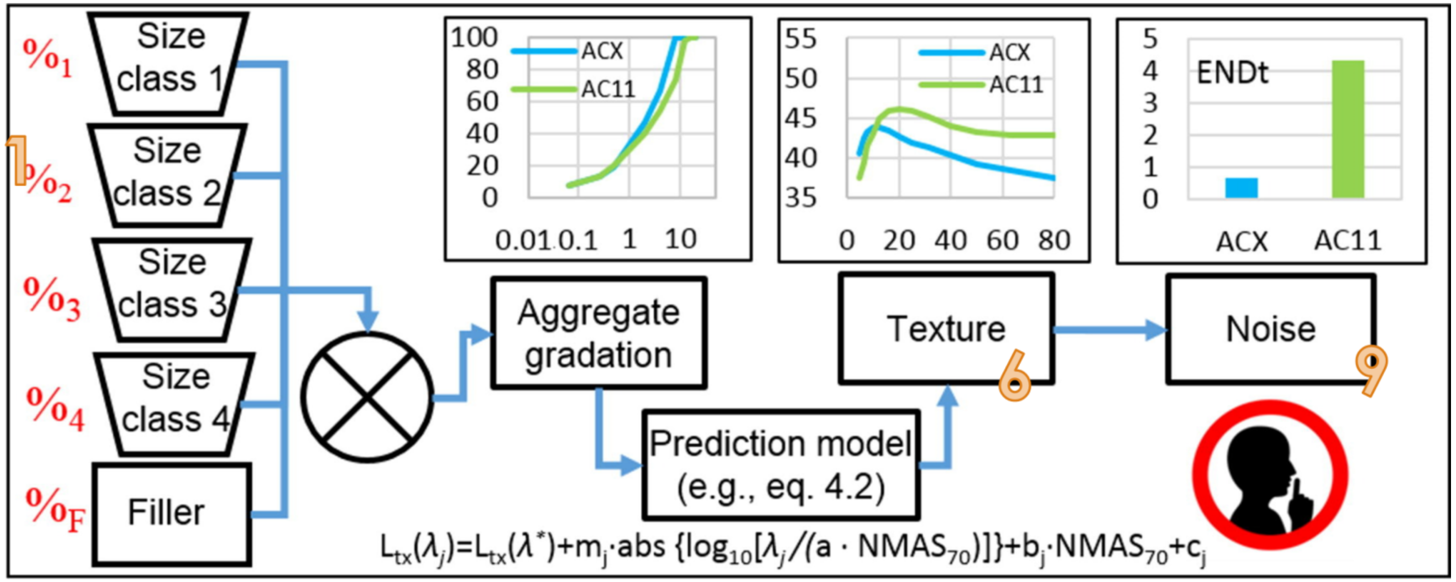
2.2 Noise-oriented design of a pavement mixture



From gradation to noise



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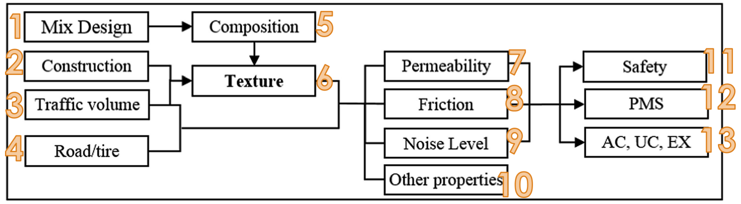
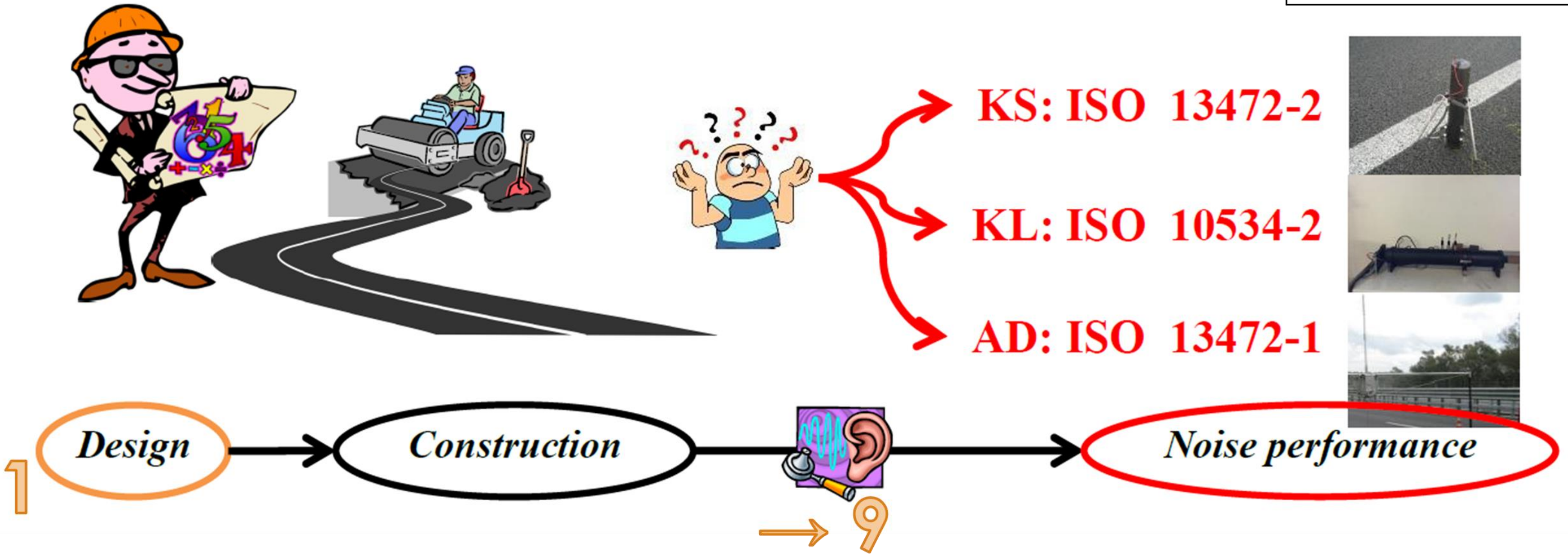


Porous mixtures (absorption validation)



Filippo G. Praticò, Rosario Fedele, Domenico Vizzari, Significance and reliability of absorption spectra of quiet pavements, Construction and Building Materials, Volume 140, 2017, Pages 274-281, ISSN 0950-0618, https://doi.org/10.1016/j.conbuildmat.2017.02.130.

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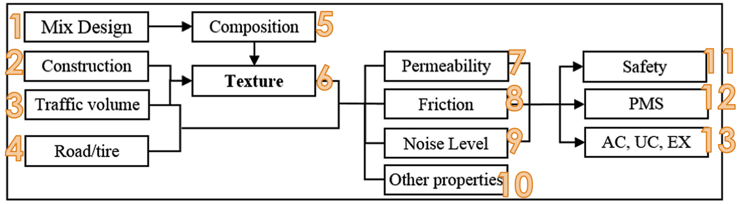
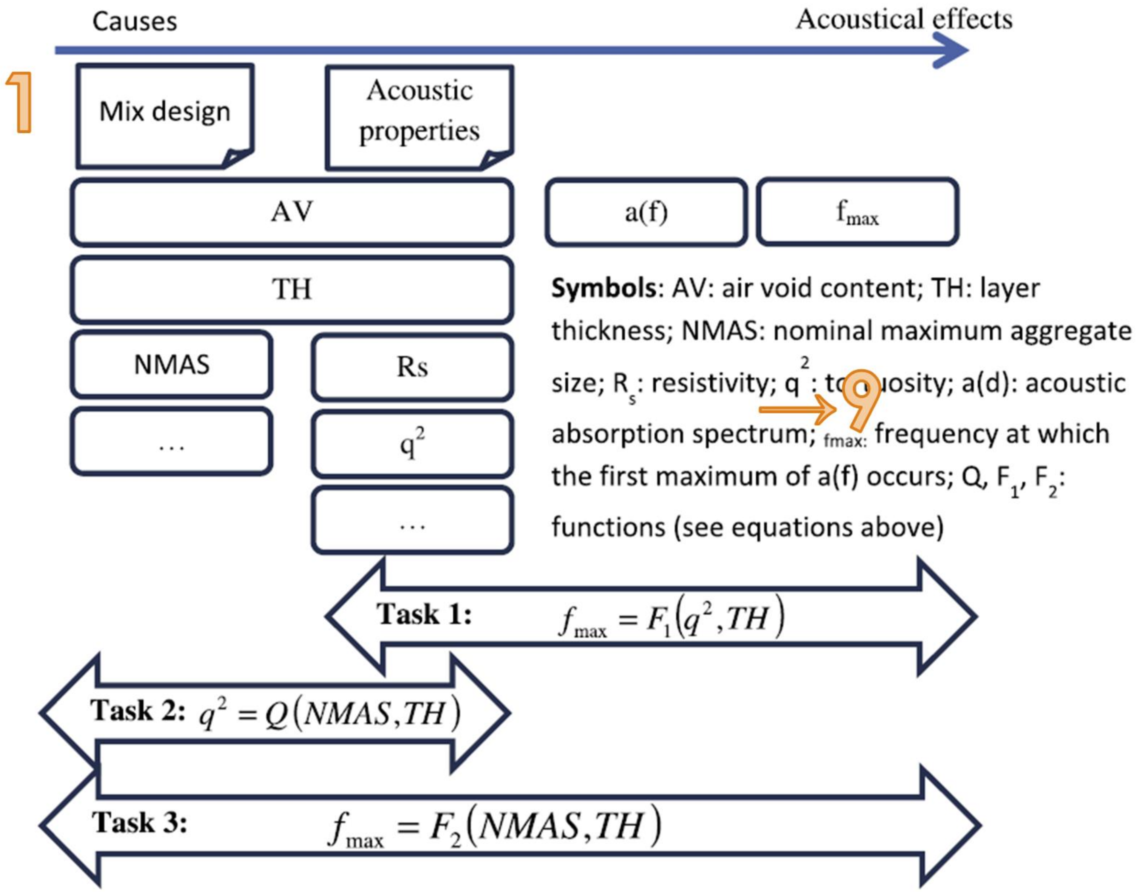
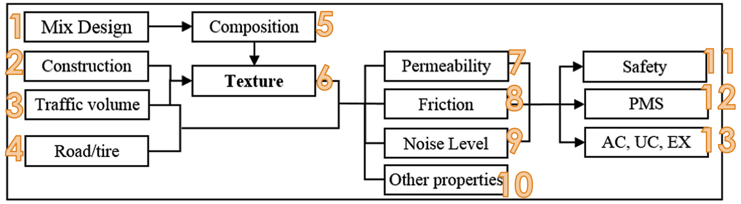


Porous mixtures (mix design and outputs)

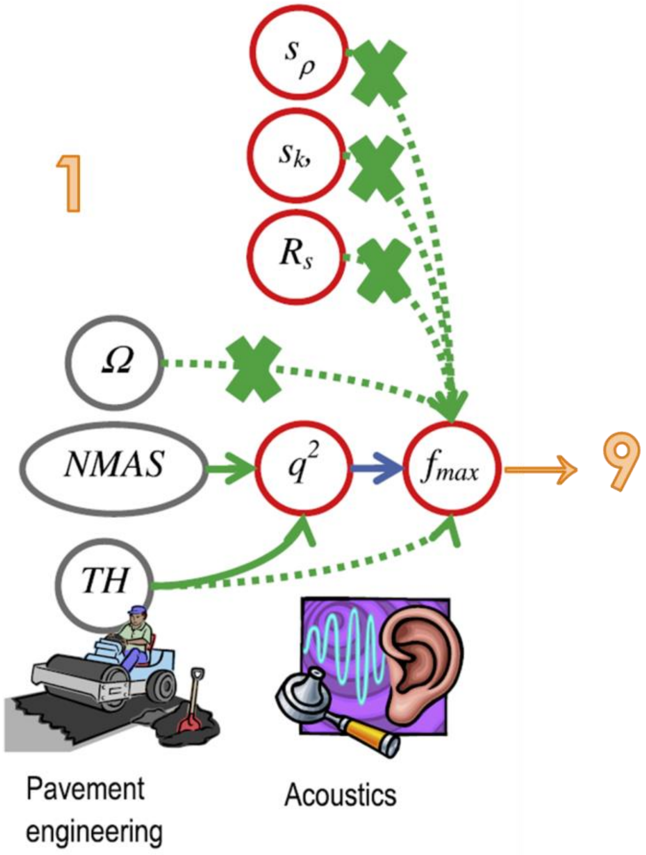


Filippo Giammaria Praticò, On the dependence of acoustic performance on pavement characteristics, Transportation Research Part D: Transport and Environment, Volume 29, 2014, Pages 79-87, ISSN 1361-9209, https://doi.org/10.1016/j.trd.2014.04.004.

2.2 Noise-oriented design of a pavement mixture



Porous mixtures (impact of porosity, NMAS, and thinckness)



Strong correlation

Weak correlation

No correlation

s_ρ, s_k: viscous and thermal factors;

R_s: resistivity (Ns/m^4);

Ω: porosity;

q^2: tortuosity;

NMAS: nominal maximum aggregate size (mm);

TH: thickness (mm).

Filippo Giammaria Praticò, On the dependence of acoustic performance on pavement characteristics, Transportation Research Part D: Transport and Environment, Volume 29, 2014, Pages 79-87, ISSN 1361-9209, https://doi.org/10.1016/j.trd.2014.04.004.

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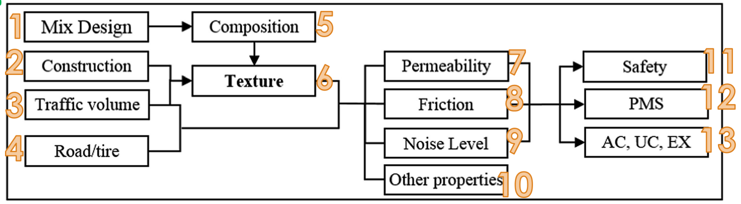

Job mix formula and texture (predicting the acoustic output based on volumetrics and gradation)

$$L_{CPX} = C_1 + C_2 \frac{D_{95}}{D_f} + C_3 \frac{V_A}{VMA}$$

- Inputs:
  - 95th percentile passing sieve (D_{95})
  - fractal dimension D_f
  - the ratio of V_A and VMA
- *Output:* L_{CPX}

M. Losa, P. Leandri, G. Licitra, Mixture design optimization of low-noise pavements Transp. Res. Rec., 2372 (1) (2013), pp. 25-33, 10.3141/2372-04

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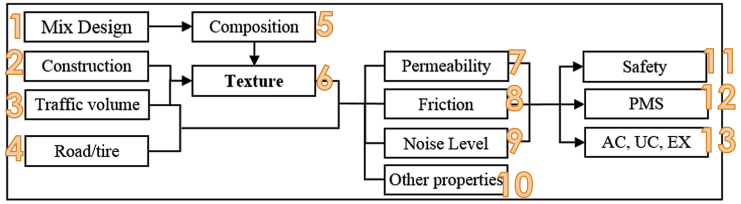
2.2 Noise-oriented design of a pavement mixture

texture (predicting the acoustic output based on volumetrics and gradation)



$$L_{CPX}(Low) = \beta_1 + a_{l1}B\% + a_{l2}VMA + a_{l3}D_f + a_{l4}D_{95}$$

$$L_{CPX}(Mid) = \beta_m + a_{m1}D_f + a_{m2}D_{45} + a_{m3}VMA + a_{m4}B\%$$

$$L_{CPX}(High) = \beta_h + a_{h1}D_f + a_{h2}D_{45}$$

- Inputs:
  - 95th, 45th percentile passing sieve (D_{95})
  - fractal dimension D_f
  - V_A, VMA, $B\%$
- *Output: LCPX* (Low (315–800 Hz; Mid (1000–1600 Hz); High(2000–5000 Hz))

M. Losa, P. Leandri, G. Licitra, Mixture design optimization of low-noise pavements
Transp. Res. Rec., 2372 (1) (2013), pp. 25-33, 10.3141/2372-04

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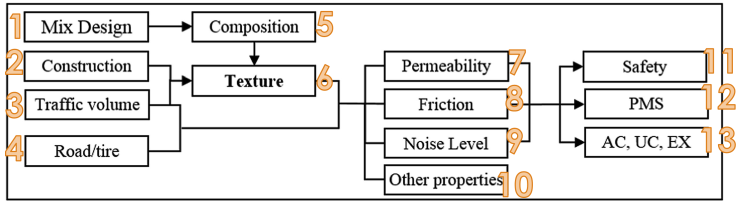
2.2 Noise-oriented design of a pavement mixture

(predicting the acoustic output based on texture and acoustic absorption)



Porous mixtures

9 1 2

$$LN(S_i) = c_1 + c_2 \times L_{TX,0.5-8} + c_3 \times L_{TX,16-63} + c_4 \times (\alpha_{mean} - \alpha_0)$$

- Output: LN(Si): tire-pavement noise level at the measurement speed Si-A weighting;
- Inputs:
  - Si: the measured speed, km/h;
  - LTX,0.5–8: Surface texture (wavelengths from 0.4 mm to 10 mm)
  - LTX,16–63: Surface texture (wavelengths from 12.5 mm to 80 mm)
  - αmean: acoustic absorption coefficient of porous asphalt mixture
  - α0: acoustic absorption coefficient of dense graded asphalt mixture (? 0.034)
  - c1, c2, c3 and c4: model coefficients which need to be adapted to the vehicle speed.

De Chen, Cheng Ling, Tingting Wang, Qian Su, Anjun Ye, Prediction of tire-pavement noise of porous asphalt mixture based on mixture surface texture level and distributions, Construction and Building Materials, Volume 173, 2018, Pages 801-810, ISSN 0950-0618, https://doi.org/10.1016/j.conbuildmat.2018.04.062.

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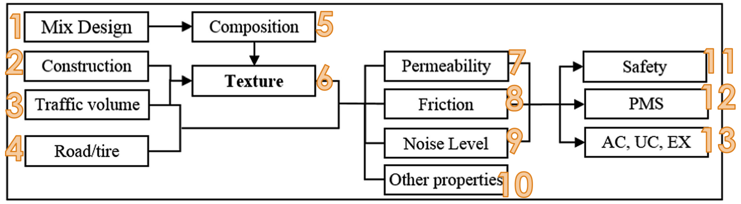
2.2 Noise-oriented design of a pavement mixture



Calculation of the Expected pass-by Noise level Difference from Texture level variation of road surface (*ENDT*)-ISO 10844:2011 **(no more in 2021)**

Output: ENDT
Inputs: Ltx, λ

$$\Delta L_{tx,\lambda} = L_{tx,\lambda} - L_{tx,ref,\lambda}$$

$$C = 0{,}25\ \Delta L_{tx,5\ mm}$$

$$B = \Sigma\ 10^{L_{mi}/10} \quad \text{for} \quad i = 1 \ldots 13$$

$$A = \Sigma\ 10^{(L_{mi} + b_i\ \Delta L_{tx,i})/10} \quad \text{for} \quad i = 1 \ldots 13$$

1

2

9 $$END_T = 10\ \lg(A/B)\ \text{dB} - C$$

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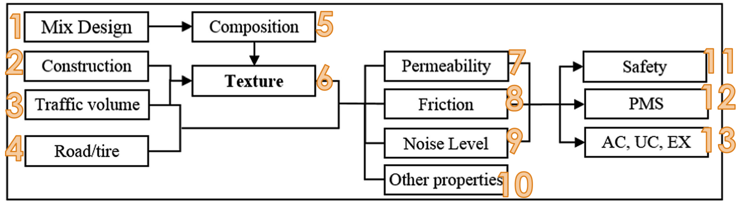
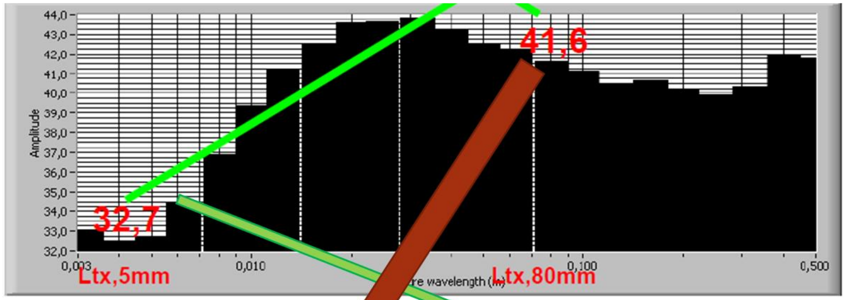
2.2 Noise-oriented design of a pavement mixture



Main variables

- Output: Estimated road noiseness level (Descornet, 2000), and Controlled Pass-By method (Goubert, 2007)
- Input: Inputs: Ltx, λ

1
2



9 $$ERNL = 60 + 0,39\ L_{T80} - 0,13\ L_{T5}$$

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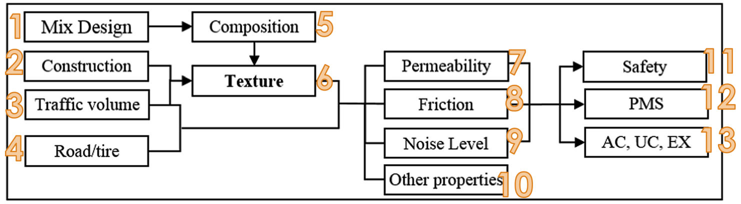
2.2 Noise-oriented design of a pavement mixture



Traffic

V: speed-velocità. Q: flows-flussi. Lp: SPL. LW: *LW,0,dir* is the directional sound power level of the specific noise (rolling, impact, squeal, braking, traction, aerodynamic, other effects) of a single vehicle in the directions ψ, ϕ, defined with respect to the vehicle's direction of movement (Stylianos Kephalopoulos, Marco Paviotti, Fabienne Anfosso-Lédée, 2012- CNOSSOS. Goubert, 2007)

$$L_{W',eq,line}(\psi,\varphi) = L_{W,0,dir}(\psi,\varphi) + 10 \times \lg\left(\frac{Q}{1000\,v}\right) \quad \text{(for } r \neq 4\text{)}$$

$$L_P \approx k \cdot 10 \log\left(\frac{v}{v_0}\right) \quad \text{(dB)}$$

9 3

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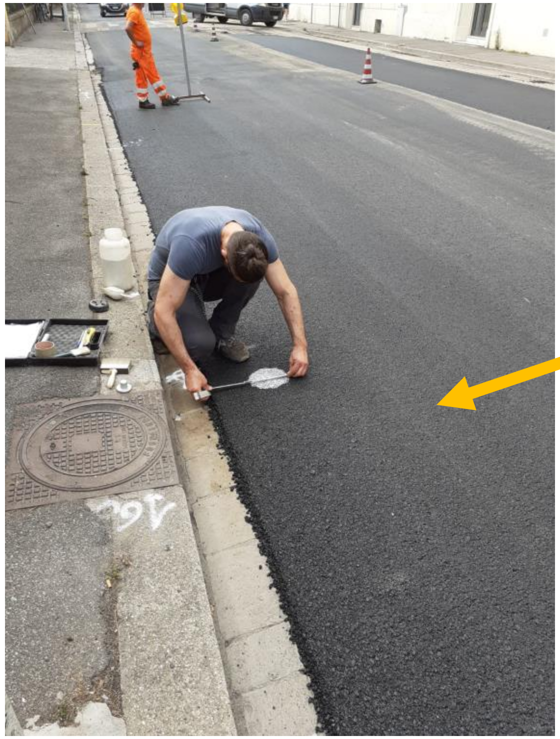
2.2 Noise-oriented design of a pavement mixture



…… Via Paisiello Florence!

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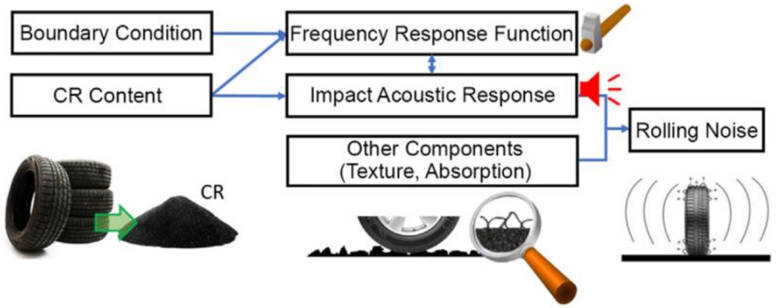
2.3 Noise-oriented design of a pavement mixture



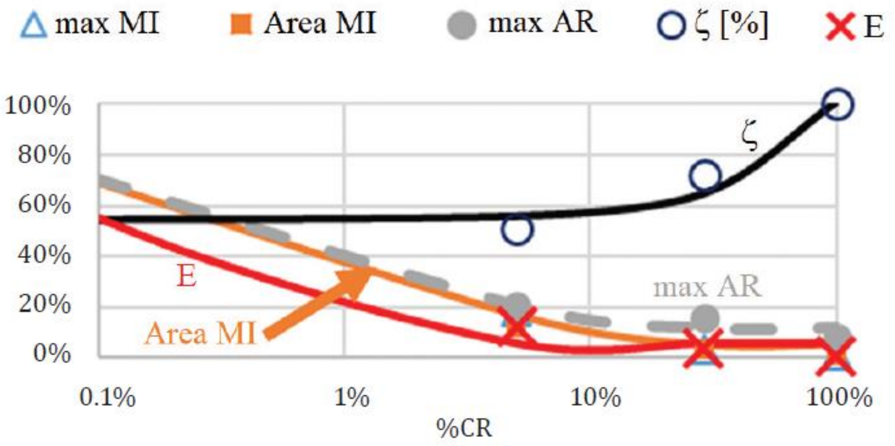
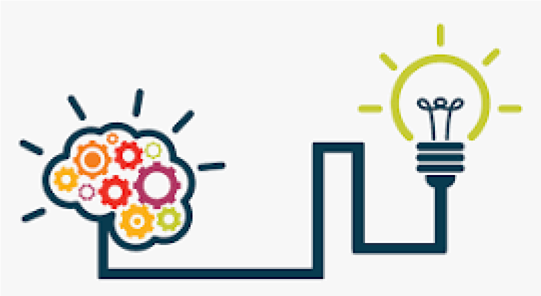


Figure 2. CR impact on noise (AR) and mechanistic response (MI, ζ, and *E*) elaborated from (Praticò et al., 2021b, 2021a)

Based on measurements, MI and K appear to be sound indicators to evaluate the RAR for frequencies in the range of 400– 3200 Hz. It should be underlined that the RAR could be influenced by the air void content of the samples.

RAR=road acoustic response



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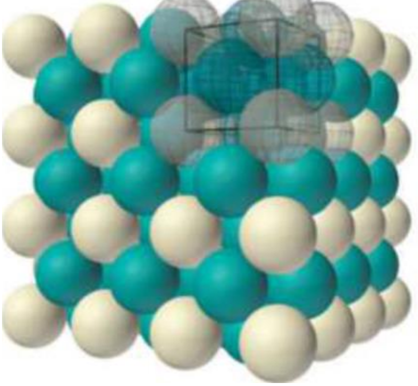


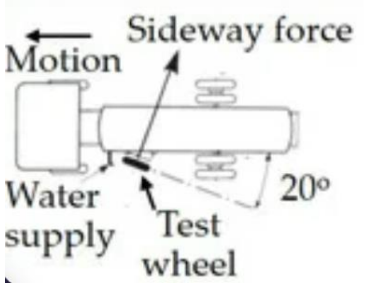
Part 3 Noise vs. texture (several specific issues)

- Hexagonal packing model→→

$$MTD = k_1 + \frac{k_2 \cdot NMAS^{\beta}}{FV^{\gamma}}$$

$$MTD = k_1 + k_2 \cdot AV^{\alpha} \cdot NMAS^{\beta}$$

- A point that emerges from the analyses is that for low-NMAS mixtures the impact of FV appears less important, while the impact of NMAS seems to be still important.
- The points above suggest using more than one predictor variable (e.g., AV and NMAS) when designing dense-graded, low-NMAS mixtures
- Conclusions: Issues may arise for low-NMAS mixtures

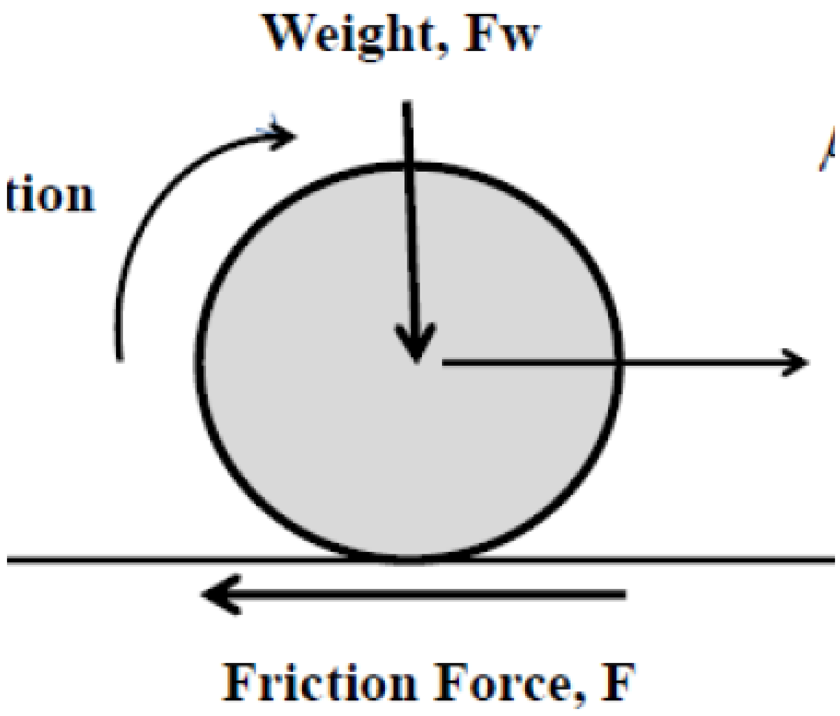


Part 4. Friction and noise

- ~wet ☚ Hysteresis ☚ macrotexture, temperature ☚ grading, material properties
- ~dry ☚ Adhesion ☚ microtexture, temperature ☚ material properties
- Friction ☚ Adhesion+Hysteresis
- Minor: 3) Rubber cohesion force (which is needed to break the interface contaminant bond); and 4) Air and fluid drag force.
- Rolling noise ☚ (macro)texture, negative/positive texture, absorption coefficient, wet or dry conditions

Friction and noise

- The friction coefficient (maximum or with blocked wheel) doesn’t seem to correlate well with the A-weighted SPL, varying the pavement type (Sandberg and Ejsmont, 2002, page 395);
- This applies also to the braking distance (braking distance vs, SPL), to the aquaplaning speed (aquaplaning speed vs. SPL), and to the wet braking distance (wet braking distance vs. Coast-By SPL), cf. (Sandberg and Ejsmont, 2002, page 396);
- Friction coefficient (maximum or with blocked wheel) doesn’t seem to correlate well with the A-weighted SPL, varying the pavement type (Sandberg and Ejsmont, 2002, page 395);
- Friction in wet conditions and high speeds is mainly affected by texture but high texture could imply high noise.
- As a matter of fact, porous asphalts imply a noise reduction (3-5 dB(A)) and have usually lower friction levels:
    - in terms of SFC this is consistent with lower thresholds in acceptance procedures
    - In terms of locked wheels, this is linked to temperature increases in the tyre and sliding on molten bitumen (cf. Sandberg and Ejsmont, 2002, page 468)
    - In terms of black ice, where de-icing is needed ((cf. Sandberg and Ejsmont, 2002, page 469).
- PERS show noise reduction (e.g., 5-15 dB(A) but friction properties are sometimes unsatisfactory (cf. Sandberg and Ejsmont, 2002, page 510)
- Microsurfacings (e.g., macroseals) have quite high friction levels and noise impacts that are comparable or lower than common friction courses.



Friction and noise-Conclusions

Noise optimisation mainly depends on "two and a half" main strategies.

Friction optimisation mainly depends on aggregate properties and grading.

Is there interference between these two objectives? Yes, there is, but it is complex.

In practice, because of the facts above, there are solutions to achieve both targets.

Nota bene. The on-site and in-plant variability may make you fail the target.

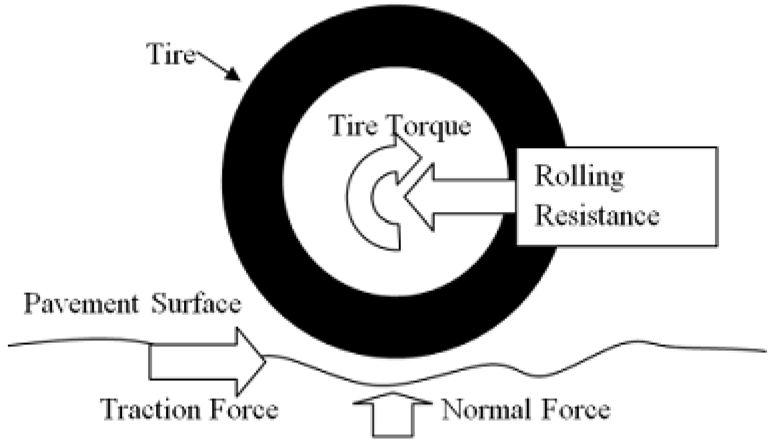
Technical challenges- Summary for friction vs. noise

First class of challenges: conflict of performance

Second class of challenges: failures deriving from in-plant and on-site variability and defects

Part 5. Noise vs. rolling resistance

- Texture impact:
  - Roughly speaking, the higher the texture, the higher the noise;
  - The higher the texture the higher the rolling resistance;
- Mechanical impedance impact:
  - The higher the mechanical impedance and modulus, the higher the Noise
  - The higher the mechanical impedance the lower the rolling resistance (?)



Rolling resistance and noise

- Rolling resistance depends on MPD and IRI and well correlates with fuel consumption.
- The higher the hardness of Tyre rubber is the higher the rolling resistance and the tyre/road noise are (Sandberg and Ejsmond, page 399). This is controversial
- Rolling resistance and A-weighed SPL have a positive correlation. (Sandberg and Ejsmond, page 399).
- Rolling resistance for PERS greatly depends on vehicle mass. Overall it is higher than for SMAs and lower than for microsurfacing. (Taryma_2018_IOP_Conf._Ser.__Mater._Sci._Eng._421_022035)
- Conclusions.
  - Apart from PERS, basically, both rolling resistance and noise (often) negatively correlate with MPD.
  - Often Rolling resistance and noise well correlate (in the sense that low-noise and low-rolling resistance pavements may be given).

Part 6 - Solutions to **Technical challenges (holistic approach)**

- *There are many functional characteristics*
- *Each one has its own expected life.*
- *Derive the minimum expected life for functional characteristics.*
- *Derive the expected life of the entire pavement*
- *Analyse and iterate*
- *Symbols. Ci*(*t*) is decay curve of the *i*th property over time, SL*C* is the specification limit of *C*, *t* is time, EXL*Ci* is expected life of *Ci*, EXLFC is expected life of the friction course FC, EXLP is expected life of the entire pavement P. Examples of *Ci*(*t*): DR(*t*) is drainability; *a*0(*t*) is acoustic absorption coefficient, MTD(*t*) is mean texture depth, PTV(*t*) is pendulum test value, typical values for n is 2 or 3.

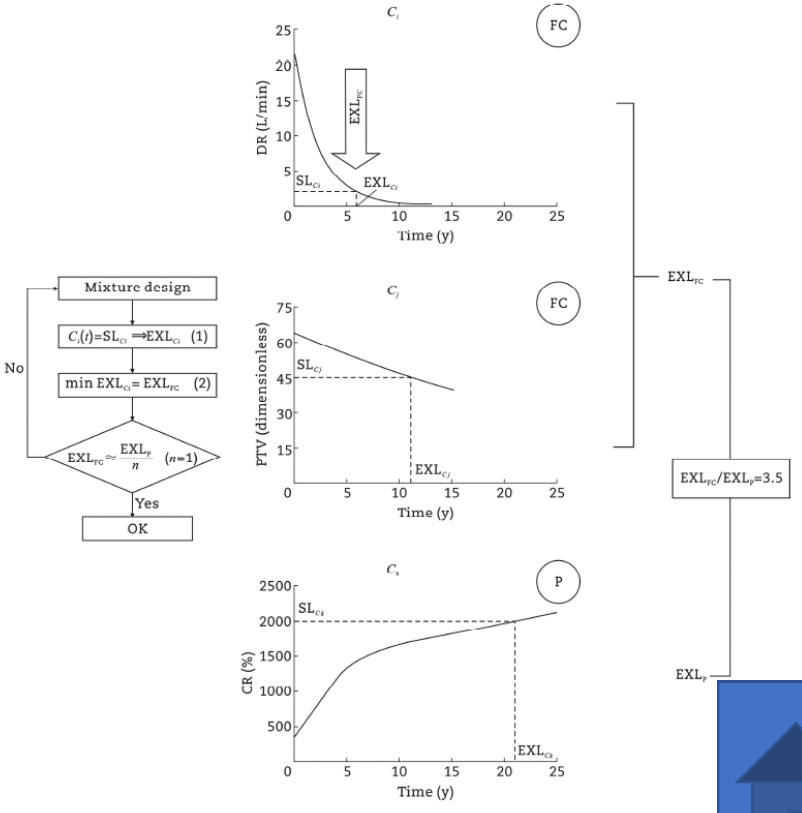


Fig. 3 Simplified schematic of method.

Main References

Projects:

- Silvia (2006)
- MIRIAM - Models for rolling resistance In Road Infrastructure Asset Management Systems-2010
- LIFE E-VIA
- LIFE SNEAK
- LIFE SILENCE (in progress)

Papers

- Praticò F.G., Fedele R., Macrotexture Prediction for Road Mixtures with Low Nominal Maximum Aggregate Size(2023) Journal of Materials in Civil Engineering, 35 (11). DOI: 10.1061/JMCEE7.MTENG-15262
- Praticò F.G., Fedele R., Road pavement macrotexture estimation at the design stage(2023) Construction and Building Materials, 364, DOI: 10.1016/j.conbuildmat.2022.129911
- Praticò F.G., Briante P.G., Colicchio G., Fedele R., An experimental method to design porous asphalts to account for surface requirements(2021) Journal of Traffic and Transportation Engineering (English Edition), 8 (3), pp. 439 – 452 DOI: 10.1016/j.jtte.2019.05.006
- Praticò F.G., Fedele R., Briante P.G., INVESTIGATION ON ACOUSTIC VERSUS FUNCTIONAL CHARACTERISTICS OF POROUS ASPHALT(2021) Baltic Journal of Road and Bridge Engineering, 16 (4), pp. 212 - 239,.DOI: 10.7250/bjrbe.2021-16.546
- Hall et al,
- Hall et al, 2009, Guide for Pavement Friction National Cooperative Highway Research Program
- Sandberg U., and Ejsmont J., Tyre/road noise. Reference book, INFORMEX.
- Praticò, F.G., Swanlund, M., George, L-A., Anfosso, F., Tremblay, G., Tellez, R., KAMIYA, K., Del Cerro, J., Van der Zwan, J., Dimitri, G.(2013). Quiet pavement technologies, Pages : 105, PIARC Ref. : 2013R10EN, ISBN : 978-2-84060-327-6.
- Lodico D., Donavan, P., CTHWANP-RT-18-365.01.1, Quieter Pavement: Acoustic Measurement and Performance, February 2018

Thank you for your attention!

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