Overview of low-volume roads in Europe

Breixo Gomez
European Asphalt Pavement Association
Technical Director

International Conference on 'New Technologies and Sustainable Materials in construction of Rural Roads (Low Volume Roads) and Bridges' – 24-26 May 2022 - New Delhi, India

First considerations

- In Europe each country has their own regulations.
- Although low-volume roads are normally included, these are normally competence of the Local/Regional Authorities, which are free to set their own design criteria.
- In this presentation:
  - Spain: hot weather and pragmatic approach based on sections catalogue.
  - UK: analytical approach and documents in English
  - Norway: particularities for cold weather

The case of Spain

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Low volume roads in Spain

The pavement design is given by a catalogue of sections depending on the subgrade and the daily traffic intensity of heavy vehicles (IMDp). Heavy vehicles are considered:

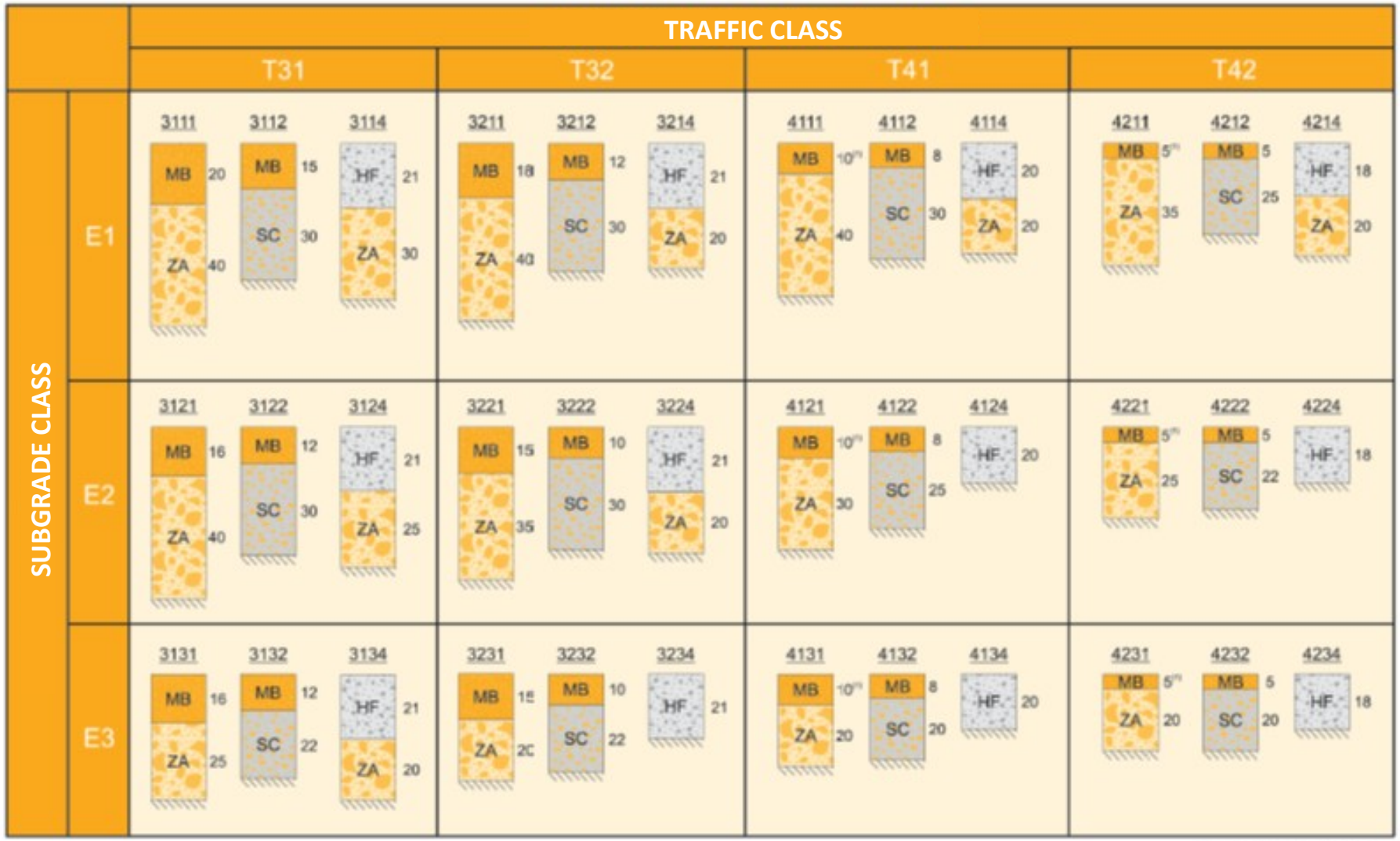
- trucks with a payload greater than 3 t, with more than 4 wheels and without a trailer
- trucks with one or more trailers
- articulated vehicles and special vehicles
- vehicles dedicated to the transport of people with more than 9 seats.

Traffic class	T00	T0	T1	T2	T31	T32	T41	T42
IMDp (heavy vehicles/day)	≥ 4 000	< 4 000 ≥ 2 000	< 2 000 ≥ 800	< 800 ≥ 200	< 200 ≥ 100	< 100 ≥ 50	< 50 ≥ 25	< 25

Subgrade class	E1	E2	E3
E_{v2} (MPa)	≥ 60	≥ 120	≥ 300

E_{v2} is the compressibility modulus at second load cycle according to plate load test (Standard NLT-357)

Low volume roads in Spain



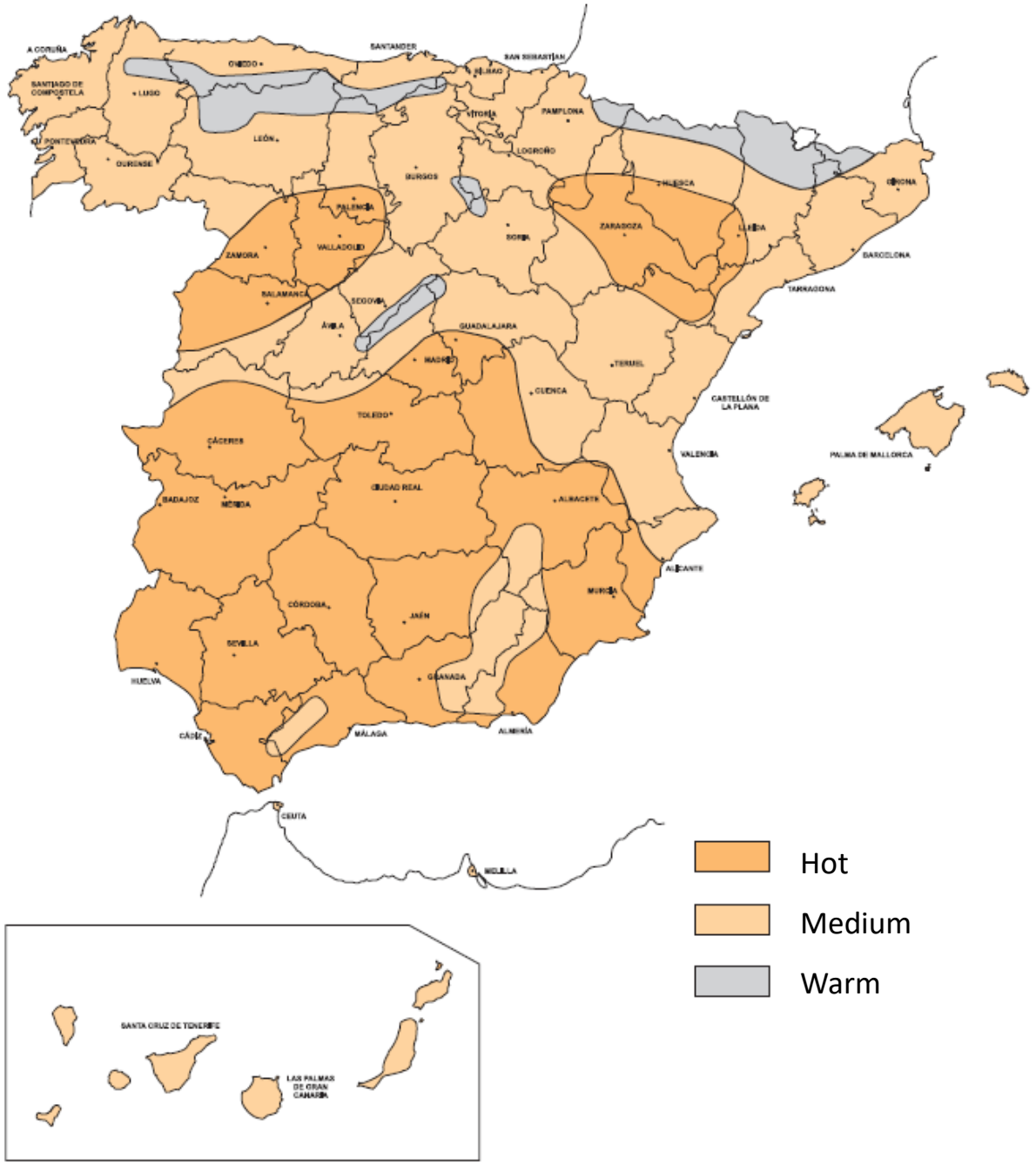
MB: Asphalt mixtures

ZA: Granular material with continuous gradation, totally or partially composed of crushed particles, used as a pavement layer.

SC: Homogeneous mixture of granular materials (gravel, granular soil or inert waste products), cement, water and possibly additives made in central, which conveniently compacted is used as a structural layer in road surfaces.

HF: Concrete

Low volume roads in Spain



Types of bitumen

Climate Area	Traffic Class					
	T00	T0	T1	T2 y T31	T32 y ARCENES	T4
Hot	35/50 BC35/50 PBM 25/55-65 PBM 45/80-65		35/50 BC35/50 PBM 25/55-65 PBM 45/80-60 PBM 45/80-65	35/50 50/70 BC35/50 BC50/70 PBM 45/80-60	50/70 BC50/70	
Medium	35/50 BC35/50 PBM 45/80-60 PBM 45/80-65		35/50 50/70 BC35/50 BC50/70 PBM 45/80-60	50/70 BC50/70 PBM 45/80-60	50/70 70/100 BC50/70	50/70 70/100 BC50/70
Warm	50/70 BC50/70 PBM 45/80-60 PBM 45/80-65		50/70 70/100 BC50/70 PBM 45/80-60			

BC = Bitumen modified with crumb rubber

Low volume roads in Spain

Other design characteristics for asphalt mixes in low traffic roads (Classes T4)

Property	**Limit**
Proportion of totally and partially crushed particles (% by mass)	**≥70**
Proportion of fully rounded particles (% by mass)	**≤10**
LA Coefficient	**≤25**
Polished stone value (PSV) for surface courses	**≥44**
Flakiness index	**≤25**
Air voids in samples according to Standard EN 12697-30 (75 blows per side)	**3-6 in surface layers** **4-7 in intermediate layers**
Wheel track average deformation slope from 5,000 to 10,000 cycles (Standard EN 12697-22) (in mm for 10^3 load cycles)	**No requirement for Traffic Class T4**

Low volume roads in Spain

Asphalt re-use / recycling

The current regulation allows up to 60% RA content. Even higher is allowed but for these cases the express authorization of the General Directorate of Roads will be mandatory. A particular technical study of the RAP —by layers and characteristics of the materials—, and of the manufacturing plant and its specific facilities will be carried out in the Project.

Mixes containing RA may only be used in binder and base courses.

They may be also used in surface courses for low heavy-traffic categories T2 to T4, when it comes to manufacturing dense or semi-dense mixes, with RA from aged surface courses.

Low volume roads in Spain

Cold Mix Asphalt

- Used specially in the centre-south of Europe (e.g. France and Spain).
- They have environmental benefits, since their manufacture does not require prior heating of the components, avoiding energy consumption and emissions of gases and fumes into the atmosphere.
- They are storable mixtures, which can help to increase transport distances and reach secondary roads placed far from asphalt manufacturing plants.
- Spreading and compaction will be carried out at room temperature environment.
- They present disadvantages, which make them not suitable for many high-traffic applications:
  - Higher air voids content
  - Lower stiffness (prone to permanent deformations)
  - Need of curing time to evaporate water
- However, in **low-volume roads**:
  - The greater flexibility allows them to adapt, without breaking, to the permanent deformations of the lower layers, especially when the subgrades are of poor quality.
  - Traffic disruptions during curing are usually not a big inconvenient.

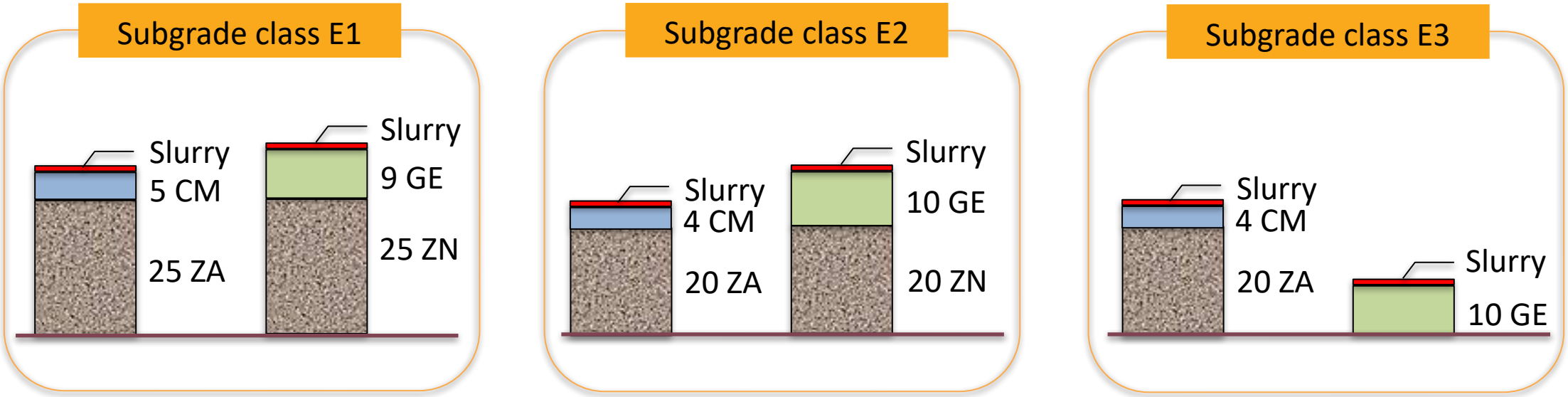
Low volume roads in Spain

Cold Mix Asphalt commonly used in low-volume roads:

- **Open cold asphalt mixtures**: Mixtures without fines, which allow us to obtain very flexible surface layers and therefore adaptable to the deformations of the subgrades and with high resistance to fatigue. Its high percentage of voids give the wearing course a high macro-texture (very safe roads) noise reduction. The large proportion of voids in the mix allows us to use medium-break bituminous emulsions with fluidizers, which facilitates their better handling for significant periods of time, several weeks, as long as they remain well stocked.
- **Grave-emulsion:** Mixtures with an aggregate with continuous granulometry and bituminous emulsion in an approximate percentage of residual bitumen of 3% to 4% that is laid and compacted at room temperature, and can also be stored once manufactured.
- **Slurry:** Mixtures made at ambient temperature of fine aggregates with a maximum size between 3 and 6 mm, with bituminous emulsion, water and possibly other components in small proportions (filler, additive, etc.).
- **Micro-surfacing:** Mixtures manufactured at ambient temperature, of fine aggregates with a maximum size between 8 and 12 mm, with bituminous emulsion, water and possibly other components in small proportions (filler, additive, etc.). They are generally made up of two layers of slurry, the first one finer and the second one thicker, where the binder used in the second layer is a modified emulsion.

Low volume roads in Spain

Examples of sections with Cold Mix Asphalt used in low-volume roads:



CM: Cold Mix
GB: Grave-emulsion
ZA: Granular material with continuous gradation, totally or partially composed of crushed particles
ZN: Granular material with continuous gradation, containing natural particles
Slurry dosing for all these sections = 8-11 kg/m^2

The case of UK

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Low volume roads in UK

- Where designing a pavement for a new carriageway, the design life shall be 40 years.

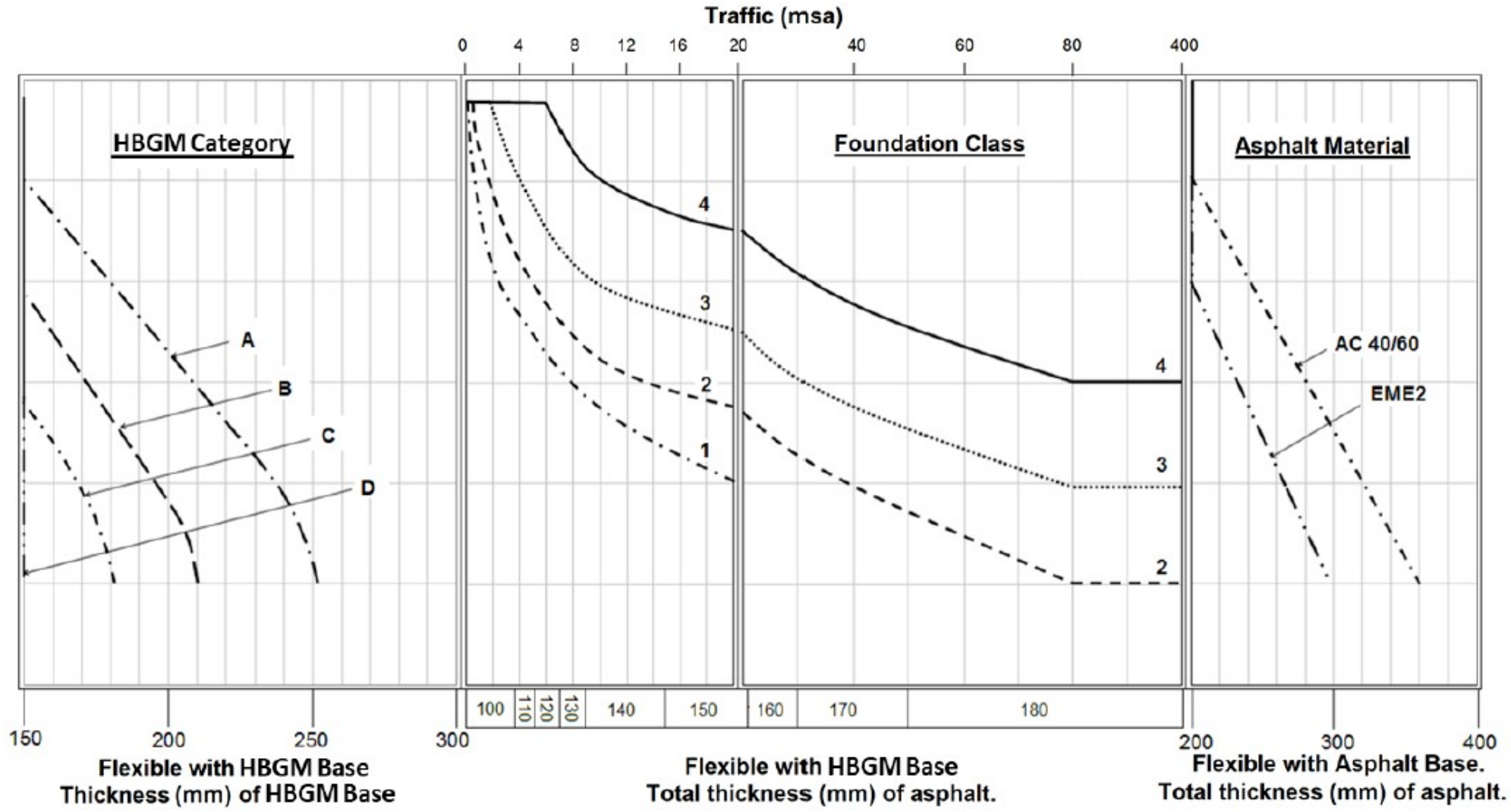
Table 2.10 Permitted base and binder course materials for flexible pavements with an asphalt base

Material type	Base	Binder course
AC 40/60	Dense and heavy-duty base materials designed in accordance with Clause 929 of MCHW Series 0900 [Ref 8.N] with the designations: AC 32 dense base 40/60 des AC 32 HDM base 40/60 des	Dense and heavy-duty binder materials designed in accordance with Clause 929 of MCHW Series 0900 [Ref 8.N] with the designations: AC 20 dense bin 40/60 des AC 32 dense bin 40/60 des AC 20 HDM bin 40/60 des AC 32 HDM bin 40/60 des
EME2	EME2 base course asphalt concrete designed in accordance with Clause 930 of MCHW Series 0900 [Ref 8.N] and targeting a penetration value of 10/20 or 15/25	EME2 binder course asphalt concrete designed in accordance with Clause 930 of MCHW Series 0900 [Ref 8.N] and targeting a penetration value of 10/20 or 15/25

Table 2.23N2 Examples of HBGM materials

HBGM Category	A	B	C	D
Crushed rock coarse aggregate: (using aggregate with a coefficient of thermal expansion $<10\times10^{-6}$ per °C)	-	Clause 822 CBGM 1 C8/10 (or T3) Clause 835 SBGM 1 C8/10 (or T3) Clause 830 FABGM 1 C8/10 (or T3)	Clause 822 CBGM 1 C12 /16 (or T4)Clause 835 SBGM 1 C12/16 (or T4)Clause 830 FABGM 1 C 12/16 (or T4)	Clause 822 CBGM 1 C15 /20 (T5)Clause 835 SBGM 1 C15/20 (or T5)Clause 830 FABGM 1 C 15/20 (or T5)
Gravel coarse aggregate: (using aggregate with a coefficient of thermal expansion $\geq10\times10^{-6}$ per °C)	Clause 822 CBGM 1 C8/10 (or T3)Clause 835 SBGM 1 C8/10 (or T3)Clause 830 FABGM 1 C8/10 (or T3)	Clause 822 CBGM 1 C12/16 (or T4) Clause 835 SBGM 1 C12/16 (or T4) Clause 830 FABGM 1 C12/16 (or T 4)	Clause 822 CBGM 1 C15 /20 (T5)Clause 835 SBGM 1 C15/20 (or T5)Clause 830 FABGM 1 C 15/20 (or T5)	-

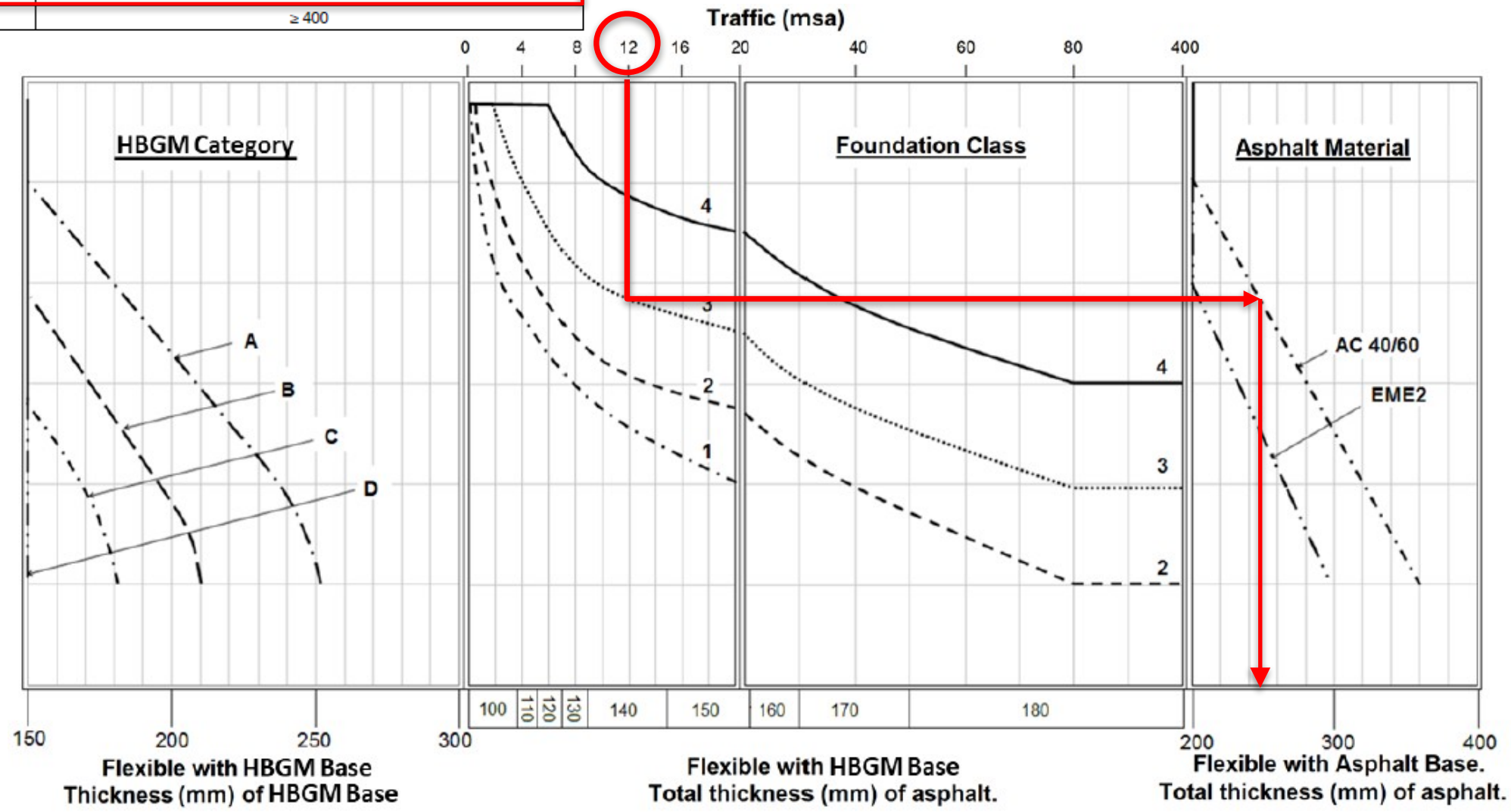
Low volume roads in UK



Low volume roads in UK

Table 3.7 Foundation classes

Foundation class	Assumed long-term confined foundation surface modulus (MPa)
1	≥ 50
2	≥ 100
3	≥ 200
4	≥ 400



Low volume roads in UK

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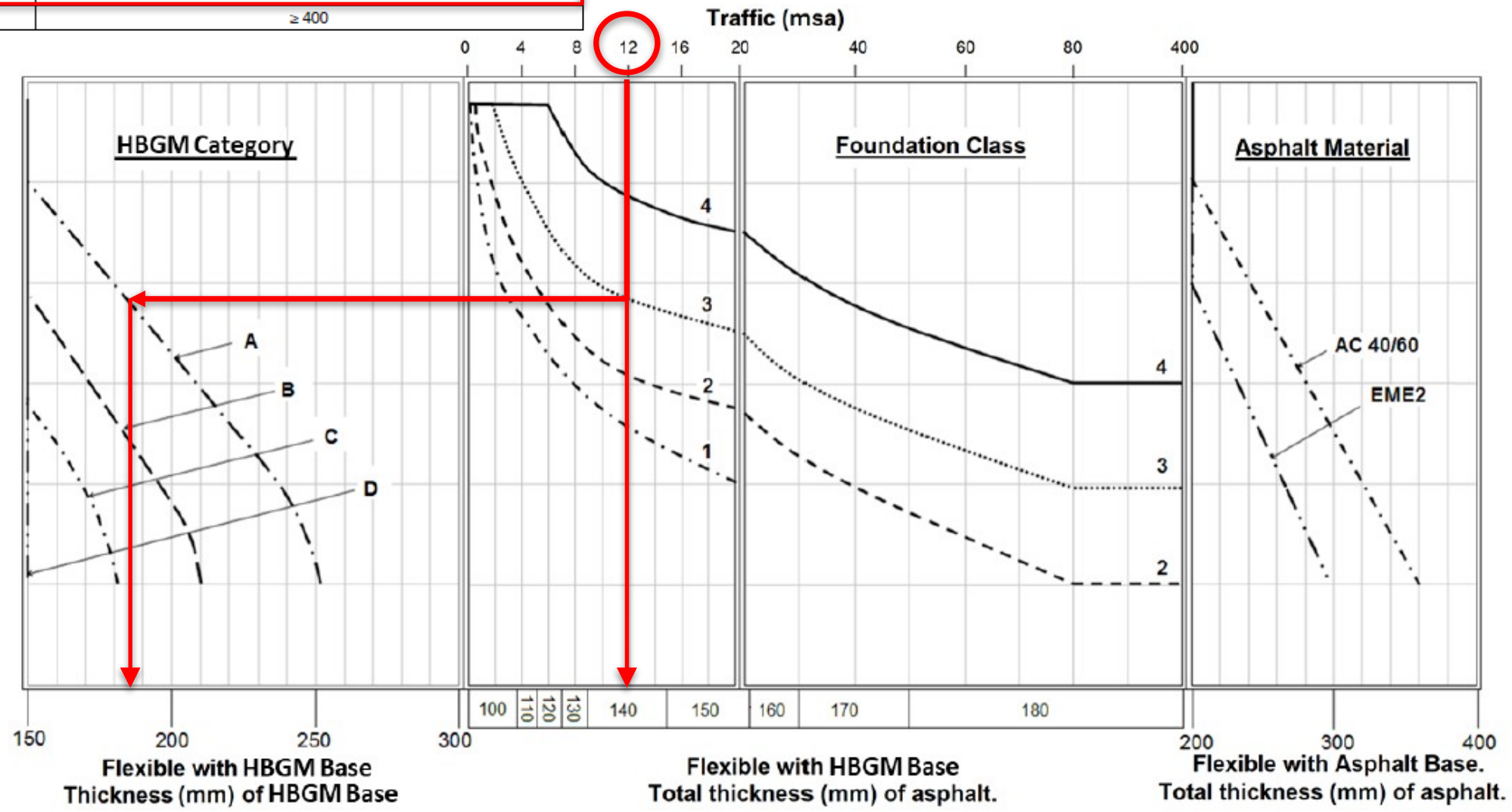

Low volume roads in UK

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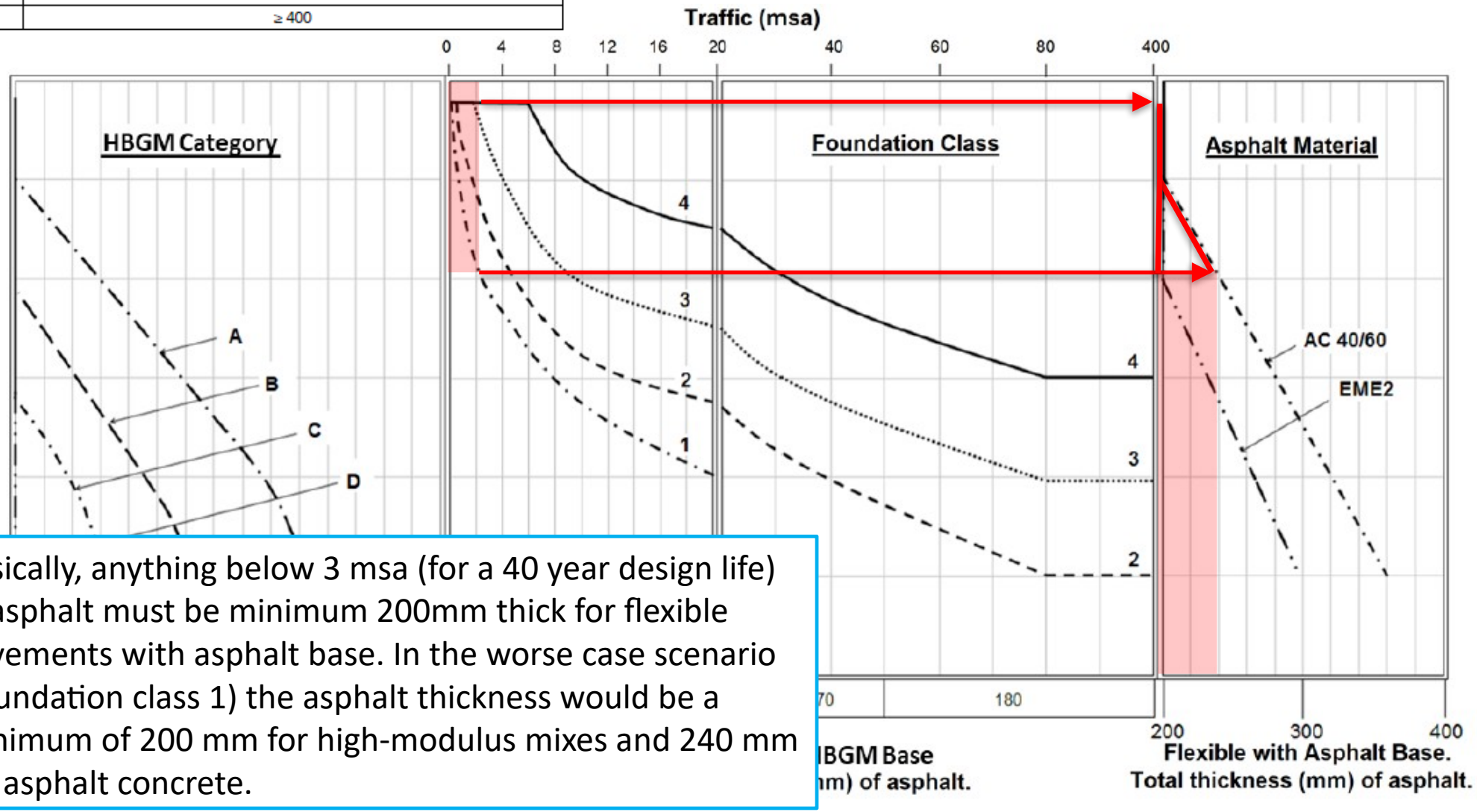
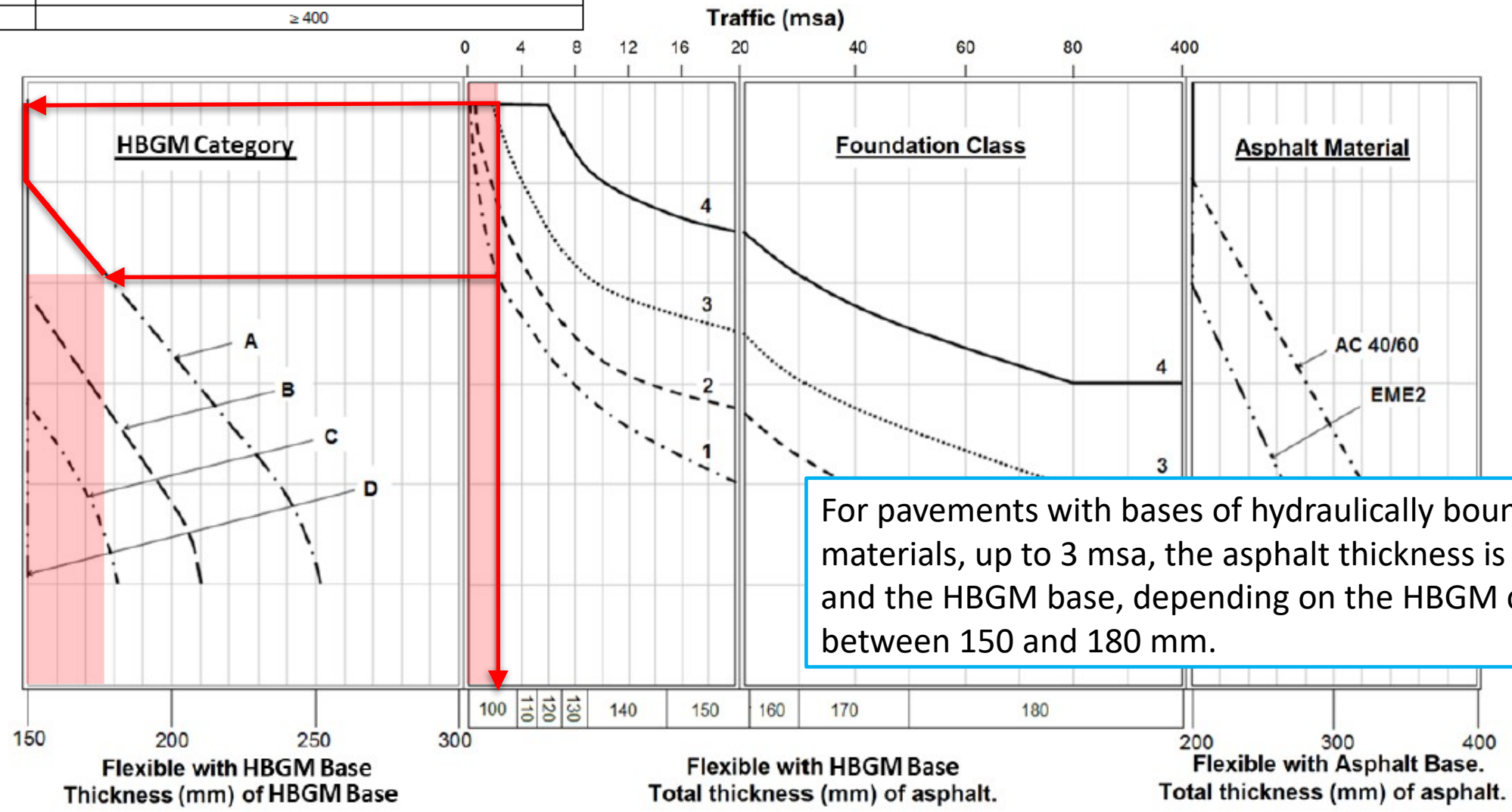


Basically, anything below 3 msa (for a 40 year design life) in asphalt must be minimum 200mm thick for flexible pavements with asphalt base. In the worse case scenario (foundation class 1) the asphalt thickness would be a minimum of 200 mm for high-modulus mixes and 240 mm for asphalt concrete.

Table 3.7 Foundation classes

Foundation class	Assumed long-term confined foundation surface modulus (MPa)
1	≥ 50
2	≥ 100
3	≥ 200
4	≥ 400

Low volume roads in UK



For pavements with bases of hydraulically bound granular materials, up to 3 msa, the asphalt thickness is 100 mm and the HBGM base, depending on the HBGM category, between 150 and 180 mm.

Low volume roads in UK

Surface courses

Coarse aggregates or chippings shall undergo polished stone value (PSV) testing in accordance with EN 1097-8 to determine the resistance to polishing under the action of traffic.

Table 3.3a PSV for chippings or coarse aggregate in surfacings excluding thin surface course systems complying with clause 942 (2019) and pavement quality concrete complying with clause 1026 (2019) of the Specification (MCHW1)

Site category	Site description	IL	PSV required for given IL, traffic level and type of site									
			Traffic (cv/lane/day) at design life									
			1 - 250	251 - 500	501 - 750	751 - 1000	1001 - 2000	2001 - 3000	3001 - 4000	4001 - 5000	5001 - 6000	Over 6000
A	Motorway	0.30	50	50	50	50	50	55	55	60	65	65
		0.35	50	50	50	50	50	60	60	60	65	65
B	Non-event carriageway with one-way traffic	0.30	50	50	50	50	50	55	55	60	65	65
		0.35	50	50	50	50	50	60	60	60	65	65
		0.40	50	50	50	55	60	65	65	65	65	68+
C	Non-event carriageway with two-way traffic	0.35	50	50	50	55	55	60	60	65	65	65
		0.40	55	60	60	65	65	68+	68+	68+	68+	68+
		0.45	60	60	65	65	68+	68+	68+	68+	68+	68+
Q	Approaches to and across minor and major junctions, approaches to roundabouts and traffic signals	0.45	60	65	65	68+	68+	68+	68+	68+	68+	HFS
		0.50	65	65	65	68+	68+	68+	HFS	HFS	HFS	HFS
		0.55	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS
K	Approaches to pedestrian crossings and other high risk situations	0.50	65	65	65	68+	68+	68+	HFS	HFS	HFS	HFS
		0.55	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS
R	Roundabout	0.45	50	55	60	60	65	65	68+	68+	68+	68+
		0.50	68+	68+	68+	68+	68+	68+	68+	68+	68+	68+
G1	Gradients 5-10% longer than 50m	0.45	55	60	60	65	65	68+	68+	68+	68+	68+
		0.50	60	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS
G2	Gradient >10% longer than 50m	0.45	55	60	60	65	65	68+	68+	68+	68+	68+
		0.50	60	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS
		0.55	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS
S1	Bends radius <500m – carriageway with one-way traffic	0.45	50	55	60	60	65	65	68+	68+	HFS	HFS
		0.50	68+	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS
S2	Bends radius <500m – carriageway with two-way traffic	0.45	50	55	60	60	65	65	68+	68+	HFS	HFS
		0.50	68+	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS
		0.55	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS

Table 3.3b PSV for coarse aggregate in thin surface course systems complying with clause 942 of the Specification (MCHW1)

Site category	Site description	IL	PSV required for given IL, traffic level and type of site									
			Traffic (cv/lane/day) at design life									
			1-250	251- 500	501- 750	751- 1000	1001- 2000	2001- 3000	3001- 4000	4001- 5000	5001- 6000	Over 6000
A	Motorway	0.30	50	50	50	50	50	50	50	53	63	63
		0.35	50	50	50	50	50	53	53	53	63	63
B	Non-event carriageway with one-way traffic	0.30	50	50	50	50	50	50	50	53	63	63
		0.35	50	50	50	50	50	53	53	53	63	63
		0.40	50	50	50	50	53	58	58	58	63	68+
C	Non-event carriageway with two-way traffic	0.35	50	50	50	50	50	53	53	58	63	63
		0.40	50	53	53	58	58	63	63	63	68+	68+
		0.45	53	53	58	58	63	63	63	63	68+	68+
Q	Approaches to and across minor and major junctions, approaches to roundabouts and traffic signals	0.45	60	65	65	68+	68+	68+	68+	68+	68+	HFS
		0.50	65	65	65	68+	68+	68+	HFS	HFS	HFS	HFS
		0.55	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS
K	Approaches to pedestrian crossings and other high risk situations	0.50	65	65	65	68+	68+	68+	HFS	HFS	HFS	HFS
		0.55	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS
R	Roundabout	0.45	50	55	60	60	65	65	68+	68+	68+	68+
		0.50	68+	68+	68+	68+	68+	68+	68+	68+	68+	68+
G1	Gradients 5-10% longer than 50m	0.45	55	60	60	65	65	68+	68+	68+	68+	68+
		0.50	60	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS
G2	Gradient >10% longer than 50m	0.45	55	60	60	65	65	68+	68+	68+	68+	68+
		0.50	60	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS
		0.55	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS
S1	Bends radius <500m – carriageway with one-way traffic	0.45	50	55	60	60	65	65	68+	68+	HFS	HFS
		0.50	68+	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS
S2	Bends radius <500m – carriageway with two-way traffic	0.45	50	55	60	60	65	65	68+	68+	HFS	HFS
		0.50	68+	68+	68+	HFS	HFS	HFS	HFS	HFS	HFS	HFS
		0.55	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS	HFS

Low volume roads in UK

Surface courses

The aggregate abrasion value (AAV) of the coarse aggregate or chippings shall be determined in accordance with Annex A EN 1097-8 to determine the durability or resistance of the aggregate to abrasion under the action of traffic.

Table 3.13 Maximum AAV of chippings, or coarse aggregates in unchipped surfaces, for new surface courses

Traffic (cv/lane/day) at design life	≤ 250	251 - 1000	1001 - 1750	1751 - 2500	2501 - 3250	>3250
Max AAV for chippings for hot rolled asphalt, surface dressing and for aggregate in slurry and microsurfacing systems	14	12	12	10	10	10
Max AAV for aggregate in thin surface course systems, CAUTS, exposed aggregate concrete surfacing and asphalt concrete surface course	16	16	14	14	12	12
Note: The maximum AAV requirement for porous asphalt is specified in Clause 938 of the Specification (MCHW SHW [Ref 2.N]).						

Low volume roads in UK

Alternative design procedures

- Alternative pavement designs are designs not following previous considerations and normally use analytical methods to model the stresses and strains and assumed material properties to determine design thicknesses. All alternative designs shall require 'departure from standard' approval by the Overseeing Organisation.
- Still, the foundation shall be designed in accordance with CD new carriageways will consider a design life of 40 years. In addition, the minimum design traffic for new roads shall be 1 msa.
- CD 226 “Design for new pavement construction” gives more information about the required steps and inputs for the alternative design.

The case of Norway

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Low volume roads in Norway

Frost protection

- Damage on roads caused by frost action is a critical problem for roads in Northern Europe.
- The damages are caused by frost heave during the winter and reduced bearing capacity in the spring thaw period.
- Different solutions to prevent the frost from penetrating down into frost susceptible subsoil have been used during the last decades.
- The easiest and most common solution may be to replace the in situ soil with sufficient amount of non frost susceptible soil.
- This solution may sometimes not be the technically or economically optimal solution. Different products that have thermal insulating effects have been used with varying degree of success.

Low volume roads in Norway

Frost protection

- The Norwegian Public Roads Administration has a long tradition in applying various kinds of thermal insulating materials for road construction applications.
- Bark was used in the 1970's and was very economical at that time (the material was available almost for free).
- Extruded polystyrene boards (XPS) were used for the first time in 1965.
- Lightweight clay and foam glass aggregates are commonly used today.

Figure 1 – Leca LWA to the left, Hasopor foam glass aggregate to the right

Low volume roads in Norway

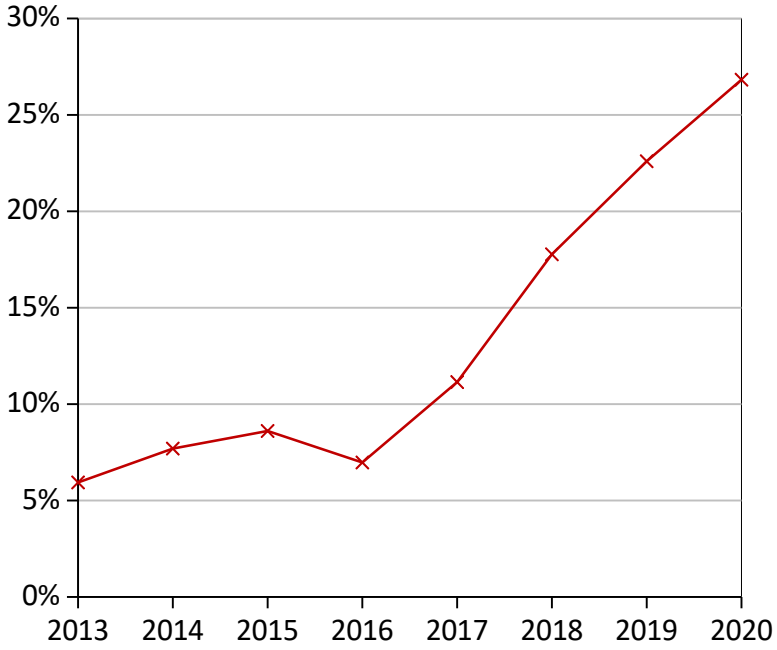
Frost protection

All requirements are described in the Road Administration handbook N200:
https://www.vegvesen.no/globalassets/fag/handboker/hb-n200-vegbygging-juli-2018.pdf

Low volume roads are defined as ADT<1500, the need for frost protection shall be assessed on sections where problems can be expected (the specifications do not stablish a minimum protection).

In general, such roads have a service life of 13-20 years and are just paved with either 100 kg/m2 Soft Asphalt or Asphalt Concrete.

Low volume roads in Norway

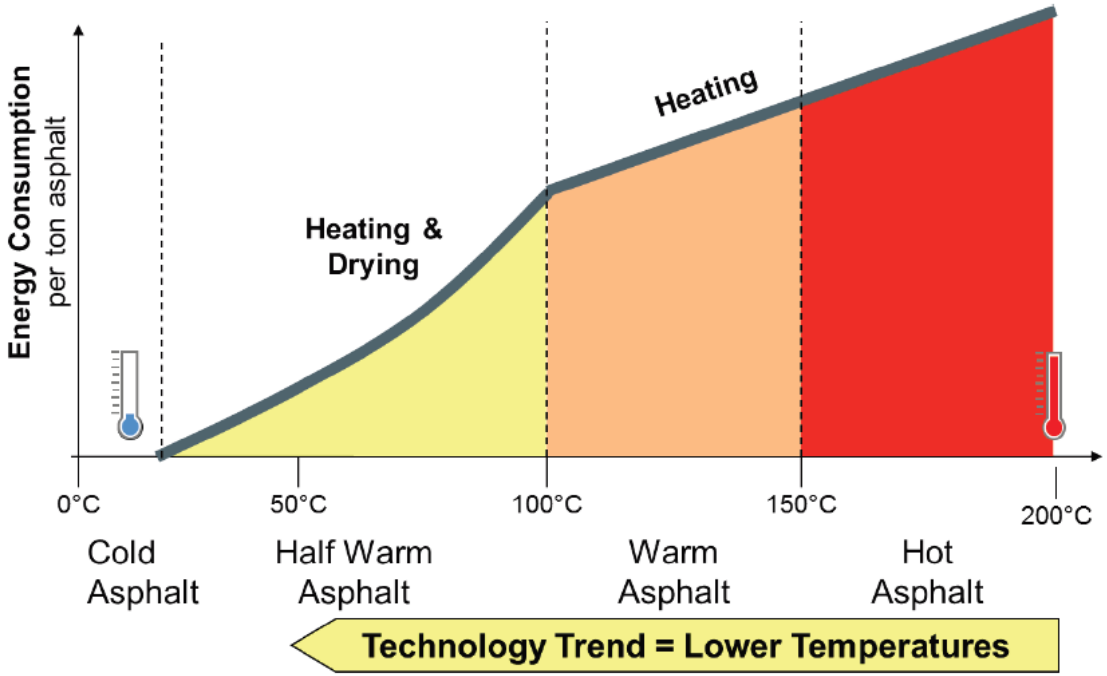


Percentage of total asphalt production done with Warm Mix Asphalt technologies in Norway over the last years

https://eapa.org/wp-content/uploads/2021/12/asphalt_in_figures_2020.pdf

Advantages of Warm Mix Asphalt

- ✓ **Environmental impact:** reduced energy consumption and emissions.
- ✓ **Health of asphalt workers:** reduced exposure to fumes and odours and a cooler working environment.
- ✓ **Paving operations:** better workability, extending the construction season and delivery distance, earlier opening of the road, reduced ageing of the bitumen.
- ✓ **Green Public Procurement:** more competitive proposals.



As a rule of thumb, the release of fume is reduced by around 50% for each 12°C reduction in temperature[1]. In addition, some studies[2] have reported energy savings of up to 35% or more for production temperatures of 100°C -140°C.

[1] *Brandt HCA, de Groot PC, A Laboratory Rig for Studying Aspects of Worker Exposure to Bitumen Fumes, American Industrial Hygiene Association Journal 60:182–190 (1999)*

[2] *Capitão, S.; Picado-Santos, L.; Martinho, F. Pavement engineering materials: Review on the use of warm-mix asphalt. Constr. Build. Mater. 2012, 36, 1016–1024, doi:10.1016/j.conbuildmat.2012.06.038.*

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