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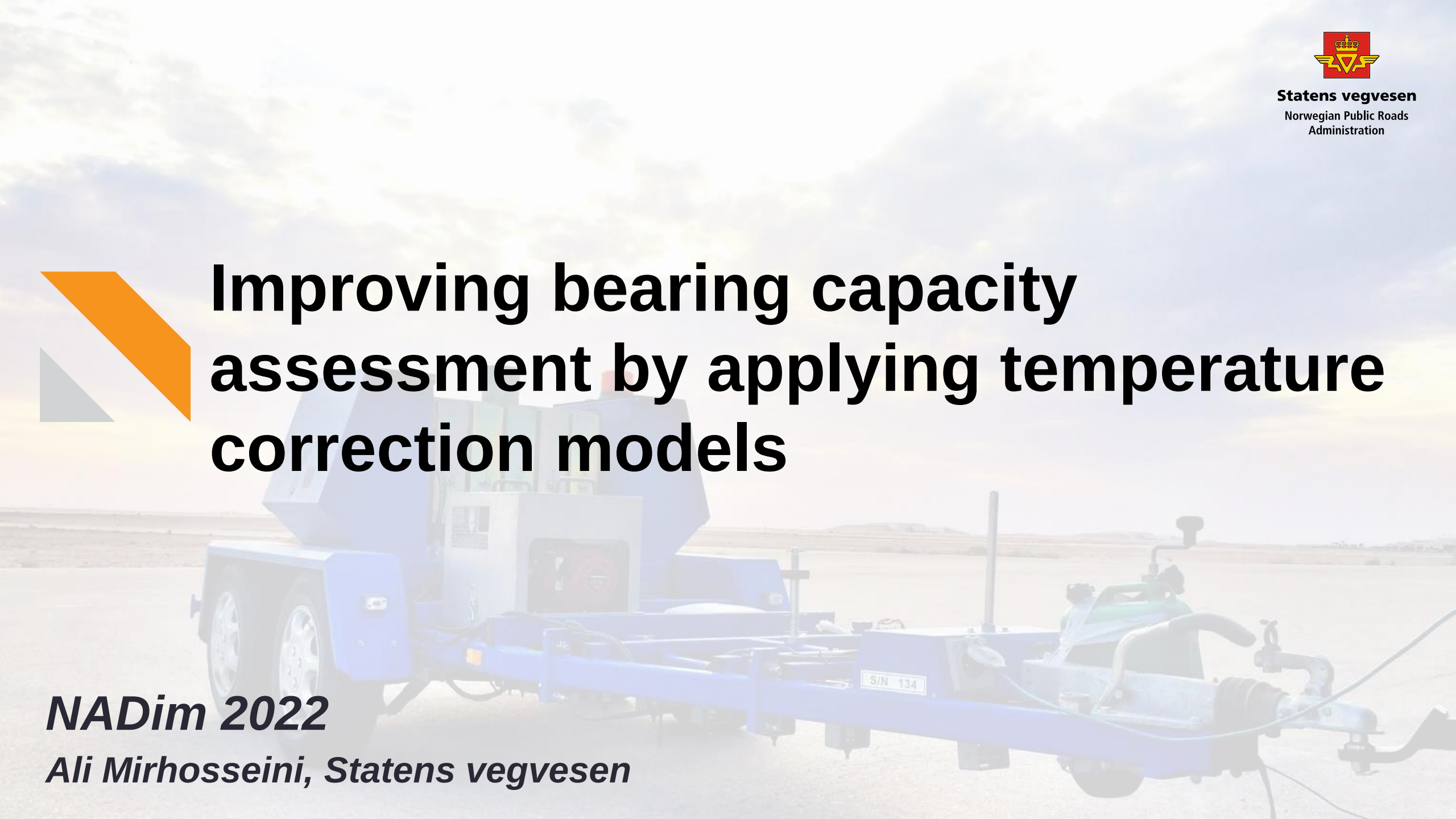
Improving bearing capacity assessment by applying temperature correction models



NADim 2022

Ali Mirhosseini, Statens vegvesen

Bearing capacity

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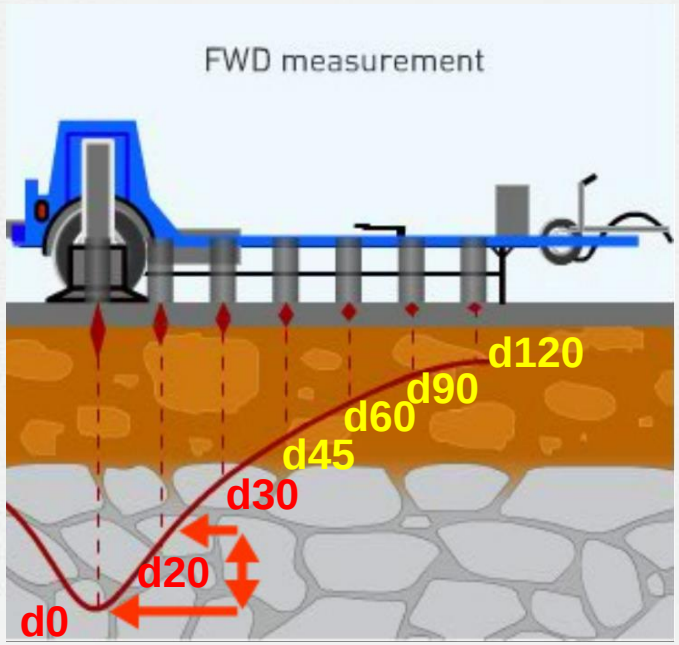
'The maximum axle load a road can handle over a period of time (the design period), while the condition of the road with normal maintenance does not fall below a defined acceptable limit (N200, Statens vegvesen).'

$$B = 11 \cdot \left(\frac{E_{dim}}{200} \right)^{0.6} \cdot \left(\frac{50}{AADT_T} \right)^{0.072}$$

B : bearing capacity (tons)
E_{dim} : design surface modulus (MPa)
$AADT_T$: annual average daily traffic for heavy vehicles

$$E_{dim} = 110 \cdot \frac{p}{(\delta_0 \cdot (\delta_0 - \delta_{200}))^{0.5}}$$

p : contact pressure (MPa)
δ_0 : deflection at the load center (mm)
δ_{200} : deflection 200 mm from the load center (mm)



Surface Curvature Index (SCI) = d0 – d20
Base Curvature Index (BCI) = d90 – d120

Why temperature?

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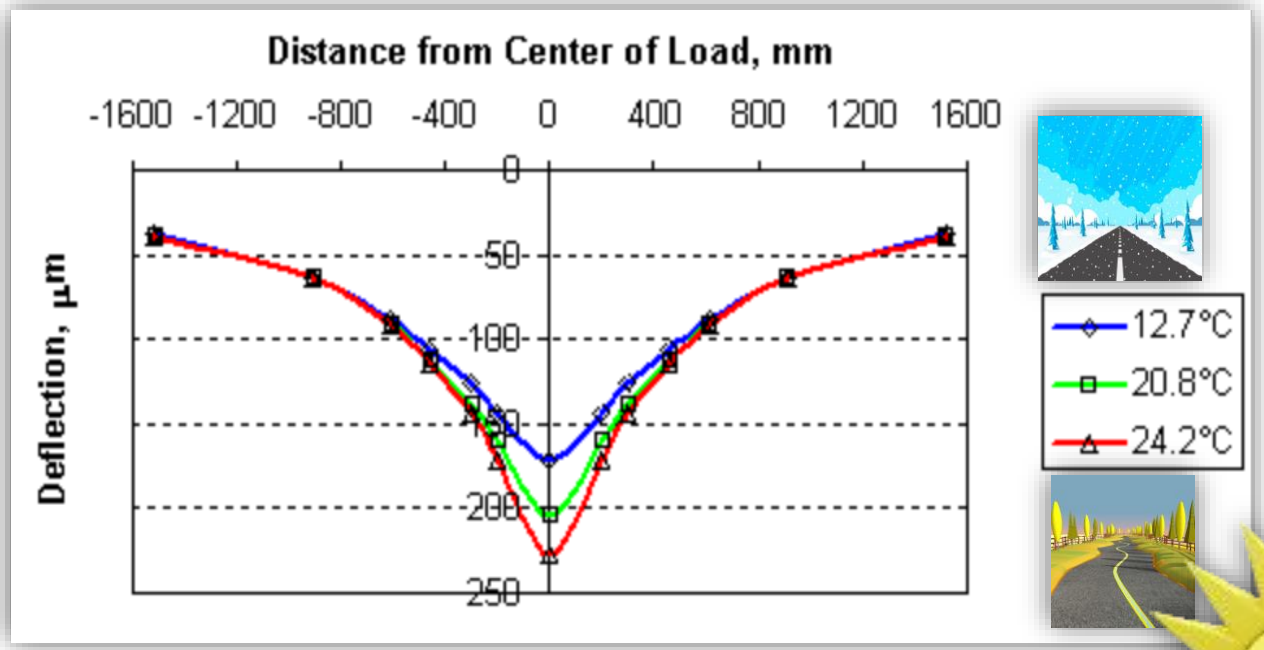
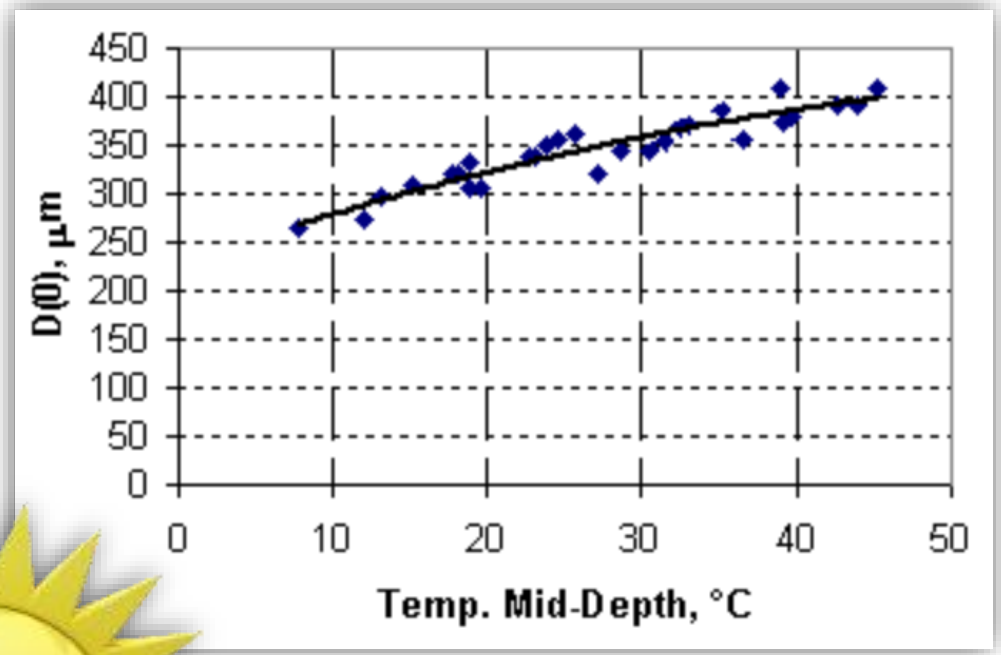
FHWA LTPP Guide to Asphalt Temperature Prediction and Correction (FHWA-RD-98-085)

With the trend toward mechanistic-empirical design methods, methods to adjust the pavement response for temperature are needed (1993).





Same section, over the course of a few hours

Same section, over the year

Mechanistic Empirical (M-E) design

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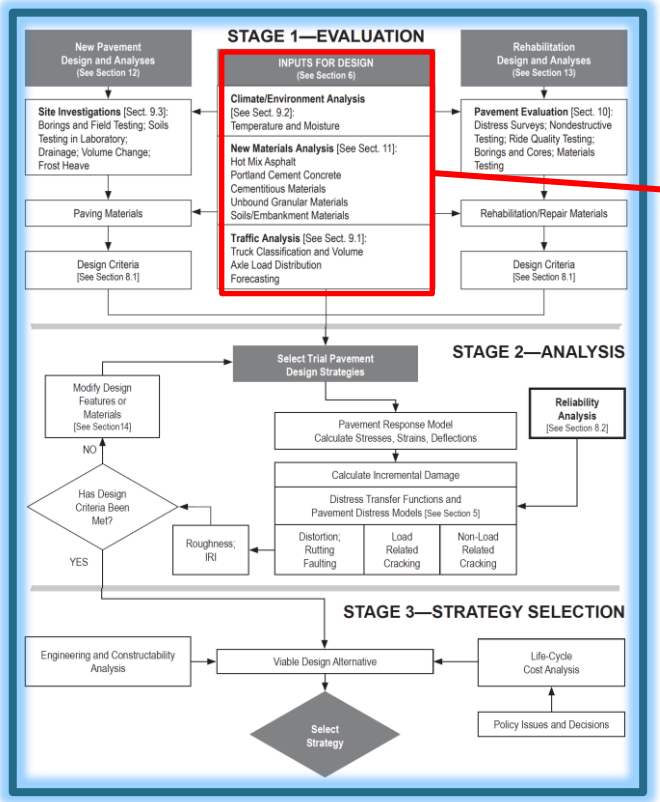
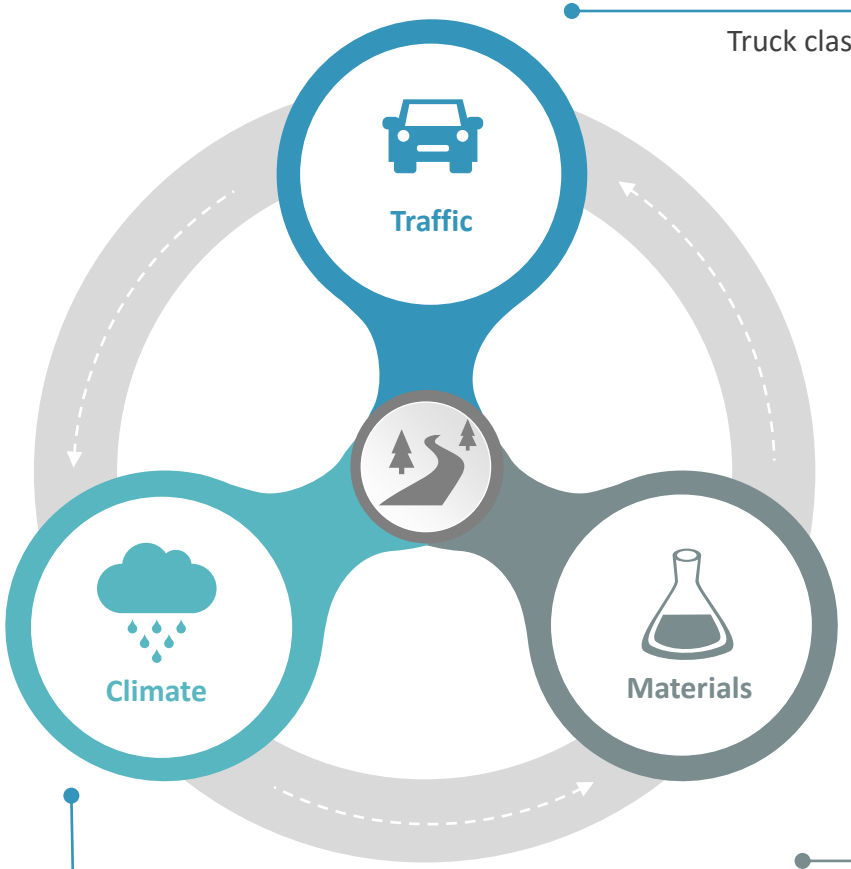


INPUTS FOR DESIGN
(See Section 6)

Climate/Environment Analysis [See Sect. 9.2]:
Temperature and Moisture

New Materials Analysis [See Sect. 11]:
Hot Mix Asphalt
Portland Cement Concrete
Cementitious Materials
Unbound Granular Materials
Soils/Embankment Materials

Traffic Analysis [See Sect. 9.1]:
Truck Classification and Volume
Axle Load Distribution
Forecasting



Traffic Analysis

Truck classification and volume

Climate / Environment Analysis

Temperature and moisture.

New Materials Analysis

Hot Mix Asphalt
Portland Cement Concrete
Unbound Granular Materials
Soils/Embankment Materials

Project research questions

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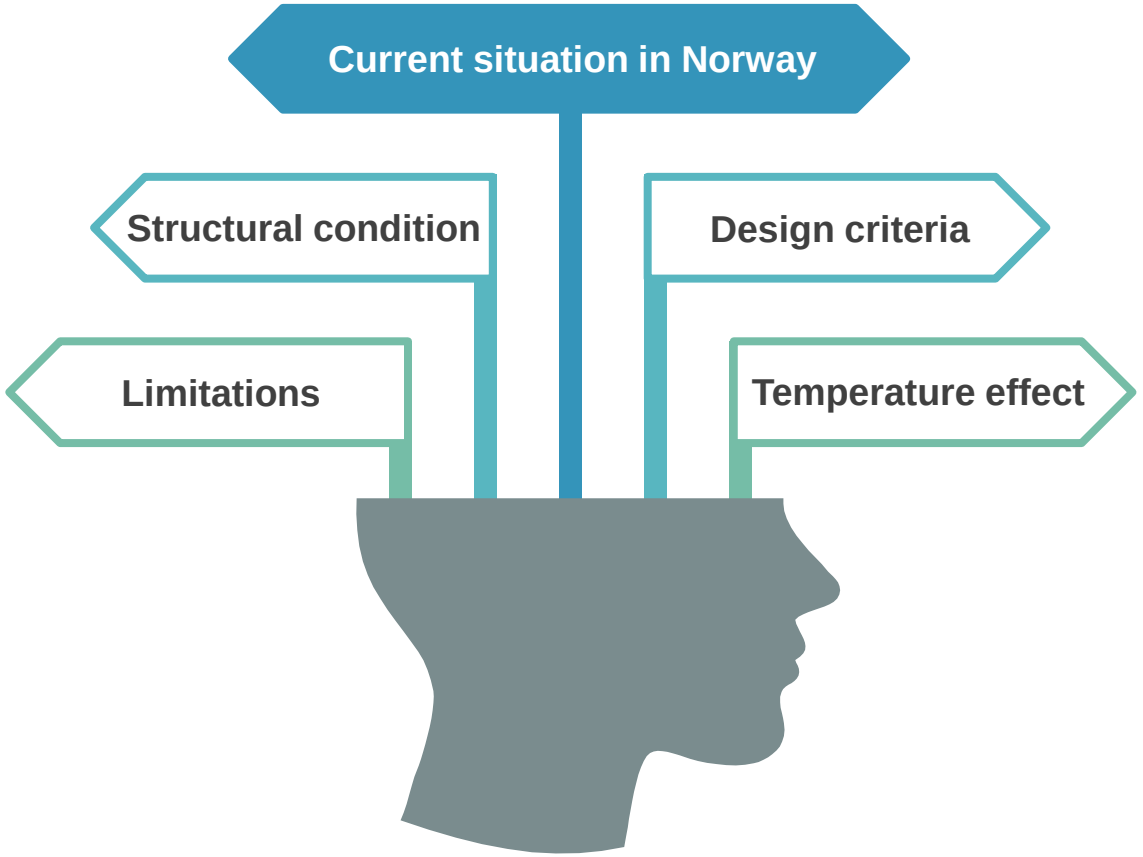
How do measure and present structural condition of roads?

By performing Falling Weight Deflectometer (FWD) and presenting FWD parameters as well as using the equation to obtain the value as bearing capacity

Why we are limited to old-fashioned equations

- Old-fashioned view to road design and technology
- Lack of enough information about the existing roads
- Limited resource and relevant research



Do we use M-E design method?

There will be a shift in the future towards M-E design method: ERAPave PP software (VegDim)

Do we consider the effect of temperature in bearing capacity calculations

No! However, a simple empirical formula developed 40 years ago is used and gives relatively acceptable results.

$$B_{korr} = \frac{B}{1{,}3 - 0{,}015 \cdot T}$$

B_{korr}: korrigert bæreevne [tonn]
B: opprinnelig bæreevne [tonn]
T: temperatur midt i dekket [°C]

The Project team

Statens vegvesen
Norwegian Public Roads Administration

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Sara Anastasio

Leif Bakløkk

Trond Østen

Ali Mirhosseini

Review of the literature

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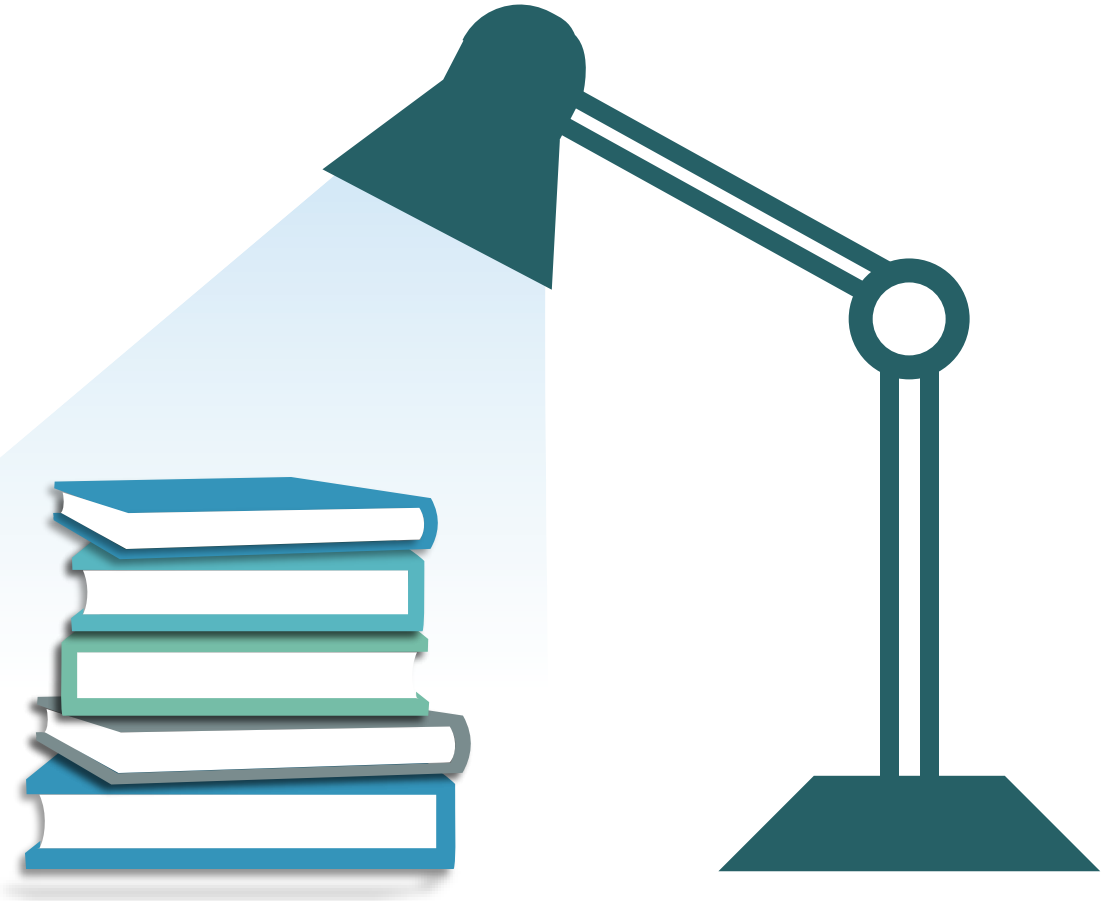
1. **Reviewing the relevant literature in Norway and around the world**
2. **Master thesis of Jørgen Sletten (Sp: Helge Mørk):**
   'Temperaturkorreksjon av nedbøyningsmålinger på vei'
3. **PhD thesis of Erling Sletten (developer of the bearing capacity formulas), 1982:**
   'Vegers Bæreevne'
4. **Possibilities for development of the current equations**



Measurements with FWD, Raptor, and TSD

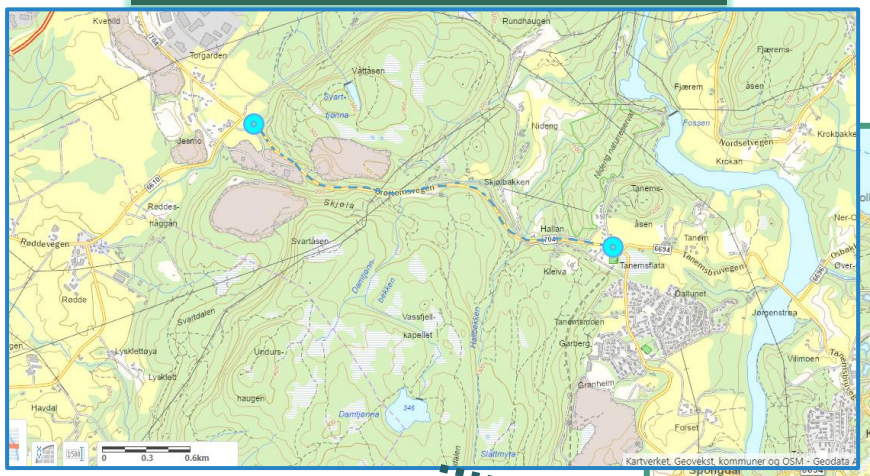
On four same stretches

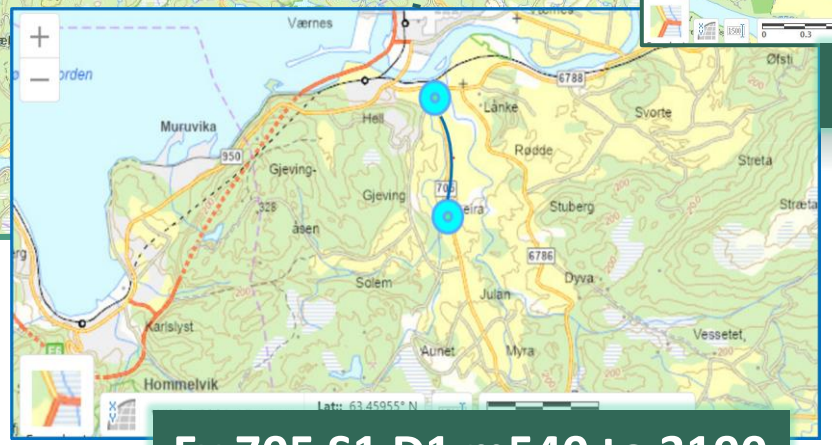
Objectives:

- Validation and comparison of data, particularly with FWD
- Finding possible correlations based on the measurements
- Further analysis of additional data from Raptor

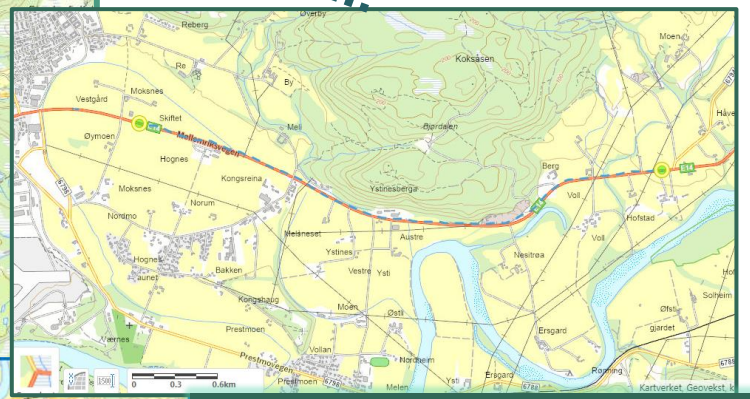
Test stretches

Fv 704 S2 D1 m0 to 2850





E14 S1 D1 m1700 to 2200



E14 S2 D1 m0 to 4000

Fv 705 S1 D1 m540 to 3190

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Measurements with FWD

Several times on the same stretches, different temperatures

Round 1
Asphalt temperature: ~ 16 °C
Air temperature: ~ 9.6 °C

Round 2
Asphalt temperature: ~ 6 °C
Air temperature: ~ 2 °C

Round 1
Asphalt temperature: ~ 19 °C
Air temperature: ~ 11 °C

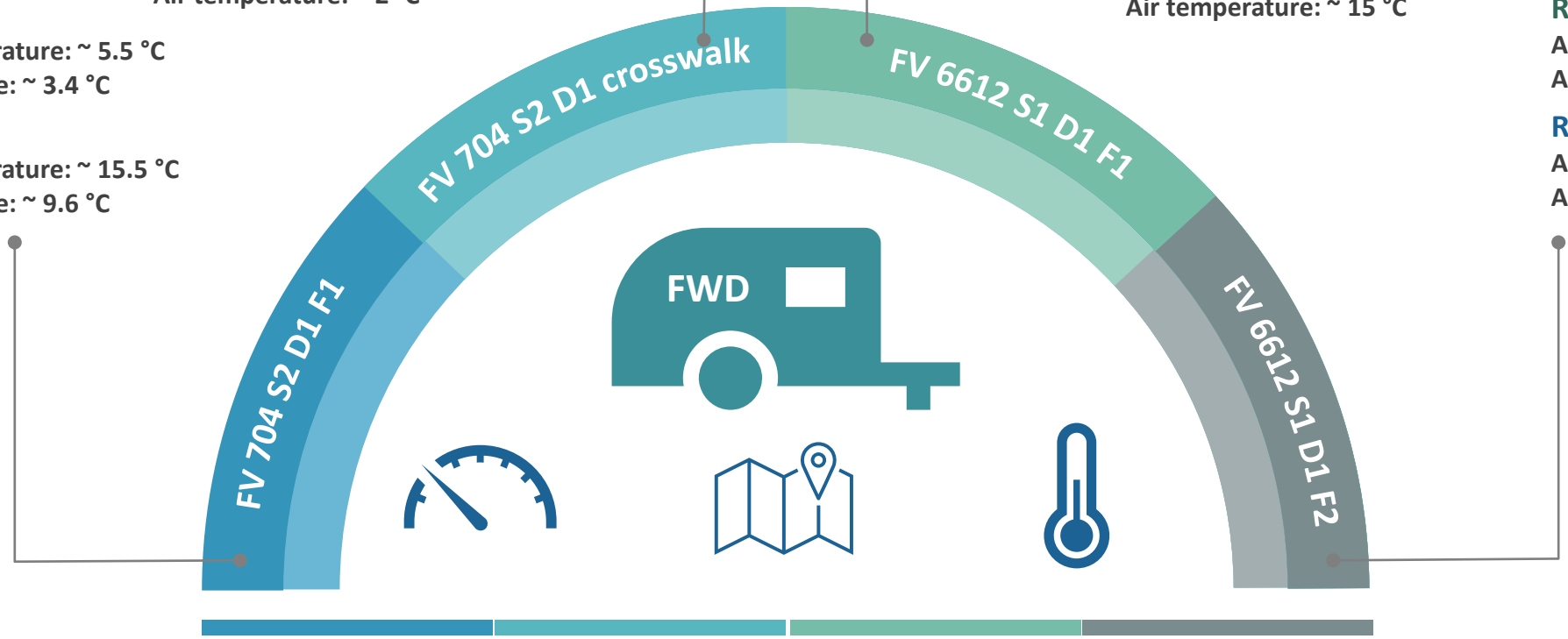
Round 2
Asphalt temperature: ~ 15 °C
Air temperature: ~ 15 °C

Round 1
Asphalt temperature: ~ 5.5 °C
Air temperature: ~ 3.4 °C

Round 2
Asphalt temperature: ~ 15.5 °C
Air temperature: ~ 9.6 °C

Round 1
Asphalt temperature: ~ 21 °C
Air temperature: ~ 13 °C

Round 2
Asphalt temperature: ~ 6.5 °C
Air temperature: ~ 3.5 °C



Present data

Fv 6612 S1 D1 F1

DTemp[°C]	LTemp[°C]
19.5	11.3
19.6	11.3
19.3	11.2
18.9	11.1
18.3	11.0
18.6	10.9
18.4	11.0
18.4	11.1
19.4	11.1
20.0	11.2
20.7	11.3
20.1	11.5
19.5	11.6
19.2	11.6
19.5	11.6
19.0	11.6

DTemp[°C]	LTemp[°C]
5.5	2.9
5.6	3.0
5.7	3.0
5.6	3.0
5.4	3.0
5.5	3.0
5.4	3.0
5.5	3.0
5.7	3.0
5.8	3.1
6.0	3.2
6.0	3.3
6.3	3.3
6.3	3.4
6.4	3.4
6.4	3.4

Round 1

Asphalt temperature: ~ 19 °C

Air temperature: ~ 11 °C

		SCI			BCI						
Bæreevne	D90	D0-D20	D0/(D0-D20)	F-diff	D90-D120	Styrke bærelag	Styrke undergrunn/ forsterkningslag	Sannsynlig undergrunn	Største svakhet i	Undergrunnens E-mod	Tøyning underkant asfalt
18.7	102.2	52.9	5.5	0.0	27.0	Meget God	God	Sand/grus	F/U	149.1	136.6
19.2	93.2	51.4	5.4	0.0	24.5	Meget God	God	Sand/grus	F/U	163.4	136.9
20.0	87.0	49.9	5.1	0.0	21.6	Meget God	God	Sand/grus	F/U	193.8	134.8
20.6	90.8	42.4	6.2	0.0	26.3	Meget God	God	Sand/grus	F/U	166.8	124.6
19.2	98.9	50.0	5.8	0.0	27.6	Meget God	God	Sand/grus	F/U	155.0	133.6
20.4	106.6	41.0	7.1	0.0	32.1	Meget God	God	Sand/grus	F/U	143.1	124.0
21.0	76.8	45.7	5.1	0.0	17.1	Meget God	Meget god	Sand/grus	F/U	209.2	125.6
21.3	69.8	43.3	5.4	0.0	21.0	Meget God	God	Sand/grus	F/U	211.3	123.2
20.8	114.7	38.1	7.6	0.0	32.9	Meget God	God	Sand/grus	F/U	135.9	116.2
18.9	110.3	48.3	6.4	0.0	31.4	Meget God	God	Sand/grus	F/U	140.4	135.5
21.0	110.0	38.9	7.0	0.0	28.4	Meget God	God	Sand/grus	F/U	140.2	113.2
19.8	75.5	50.9	5.0	0.0	21.1	Meget God	God	Sand/grus	B/F	197.0	135.9
17.2	94.3	66.6	4.7	0.0	26.4	Meget God	God	Sand/grus	B/F	161.3	156.8
16.1	100.2	71.6	5.1	0.0	23.0	Meget God	God	Sand/grus	F/U	153.4	180.9
15.2	126.2	71.3	6.2	0.0	36.5	Meget God	God	Sand/grus	F/U	124.6	198.4
17.4	105.3	56.3	6.2	0.0	30.5	Meget God	God	Sand/grus	F/U	146.3	165.9

Round 2

Asphalt temperature: ~ 15 °C

Air temperature: ~ 15 °C

		SCI			BCI						
Bæreevne	D90	D0-D20	D0/(D0-D20)	F-diff	D90-D120	Styrke bærelag	Styrke undergrunn/ forsterkningslag	Sannsynlig undergrunn	Største svakhet i	Undergrunnens E-mod	Tøyning underkant asfalt
24.3	104.9	32.3	7.8	0.0	26.4	Meget God	God	Sand/grus	F/U	146.6	107.0
24.5	95.2	32.2	7.7	0.0	21.9	Meget God	God	Sand/grus	F/U	159.9	110.2
22.9	97.6	40.6	6.1	0.0	26.5	Meget God	God	Sand/grus	F/U	172.7	111.2
25.7	90.5	30.2	7.5	0.0	23.5	Meget God	God	Sand/grus	F/U	167.5	98.5
24.7	101.7	31.2	8.0	0.0	26.6	Meget God	God	Sand/grus	F/U	150.8	103.5
25.4	102.9	28.4	8.8	0.0	26.2	Meget God	God	Sand/grus	F/U	149.2	100.1
27.5	70.4	28.4	6.8	0.0	19.9	Meget God	Meget god	Sand/grus	F/U	210.3	96.8
26.5	72.6	30.1	6.8	0.0	21.5	Meget God	God	Sand/grus	F/U	204.3	101.2
26.6	109.3	25.2	9.5	0.0	29.7	Meget God	God	Sand/grus	F/U	141.2	89.8
24.3	119.4	30.6	8.8	0.0	36.8	Meget God	God	Sand/grus	F/U	134.8	104.3
27.5	106.0	23.9	9.5	0.0	26.7	Meget God	God	Sand/grus	F/U	146.3	88.2
26.5	74.7	30.6	6.6	0.0	16.5	Meget God	Meget god	Sand/grus	F/U	199.1	99.4
21.6	93.4	44.1	6.3	0.0	26.4	Meget God	God	Sand/grus	F/U	163.1	131.8
19.5	102.0	51.6	6.5	0.0	29.1	Meget God	God	Sand/grus	F/U	150.9	157.0
17.2	130.7	63.0	6.5	0.0	33.7	Meget God	God	Sand/grus	F/U	120.5	177.4
19.8	104.2	49.7	6.5	0.0	28.3	Meget God	God	Sand/grus	F/U	147.5	150.2

Present data

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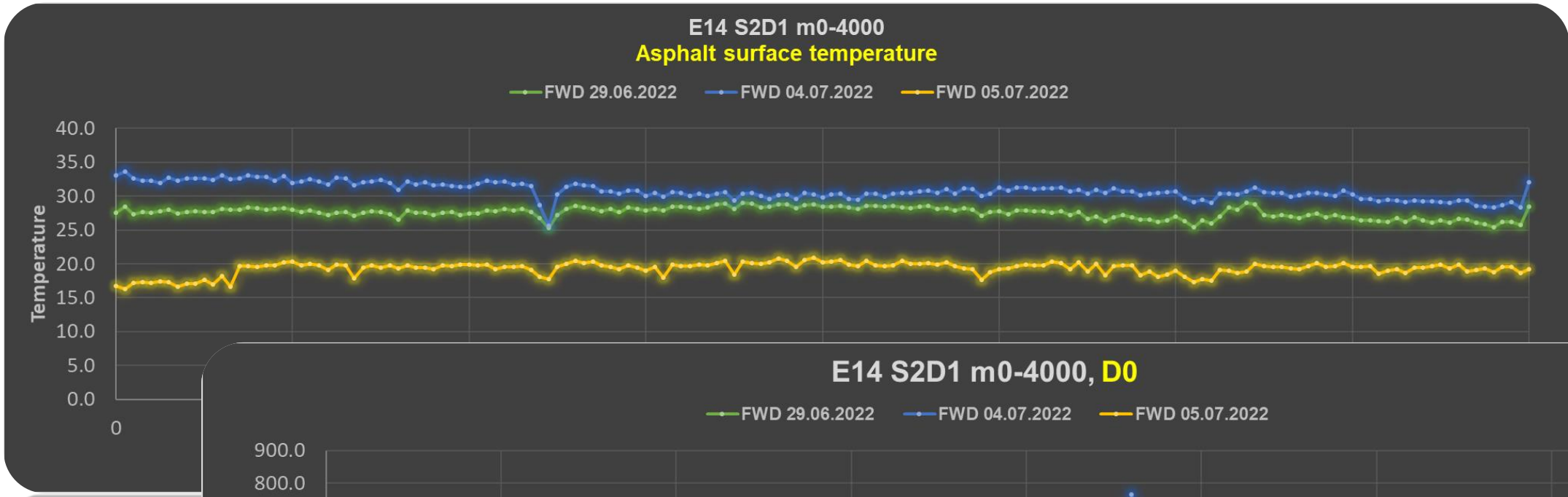

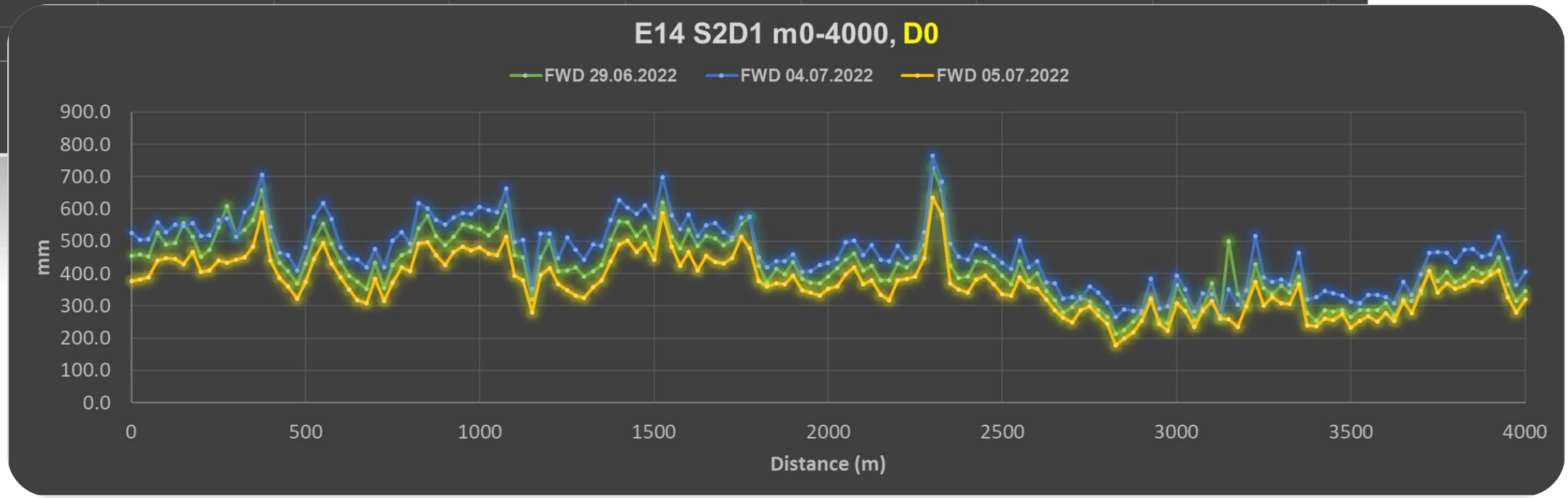

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Possibilities for development

Carrying out core drilling to determine pavement information (e.g., layers thickness) to include E-modulus in estimation and consequently performing backcalculation analysis

Use of temperature prediction models (e.g., BELLS), correlation analysis, calibrating based on Norwegian data

Use of backcalculation, determining deflection factors, calculating E-modulus, and calibrating

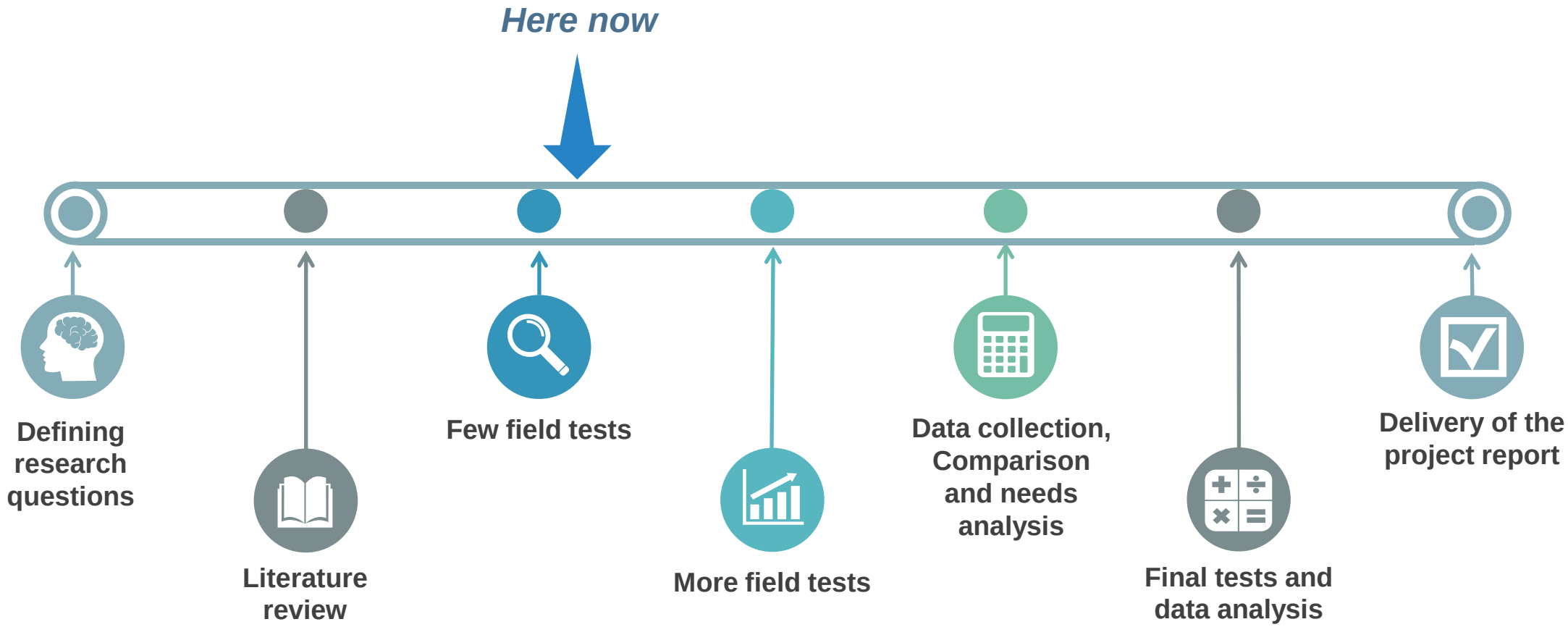
Calibrating the formulas that we currently have based on available and more measurements

?

Practical / national level

Project level

Project status



Limitations / risk factors

1. Lack of enough information on the road's construction
2. Challenges with performing FWD on E6 (main roads)
3. Carrying out FWD measurements is costly
4. Limited test area cannot be a good representative of whole Norway
5. What do you think … ?

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Thank you!