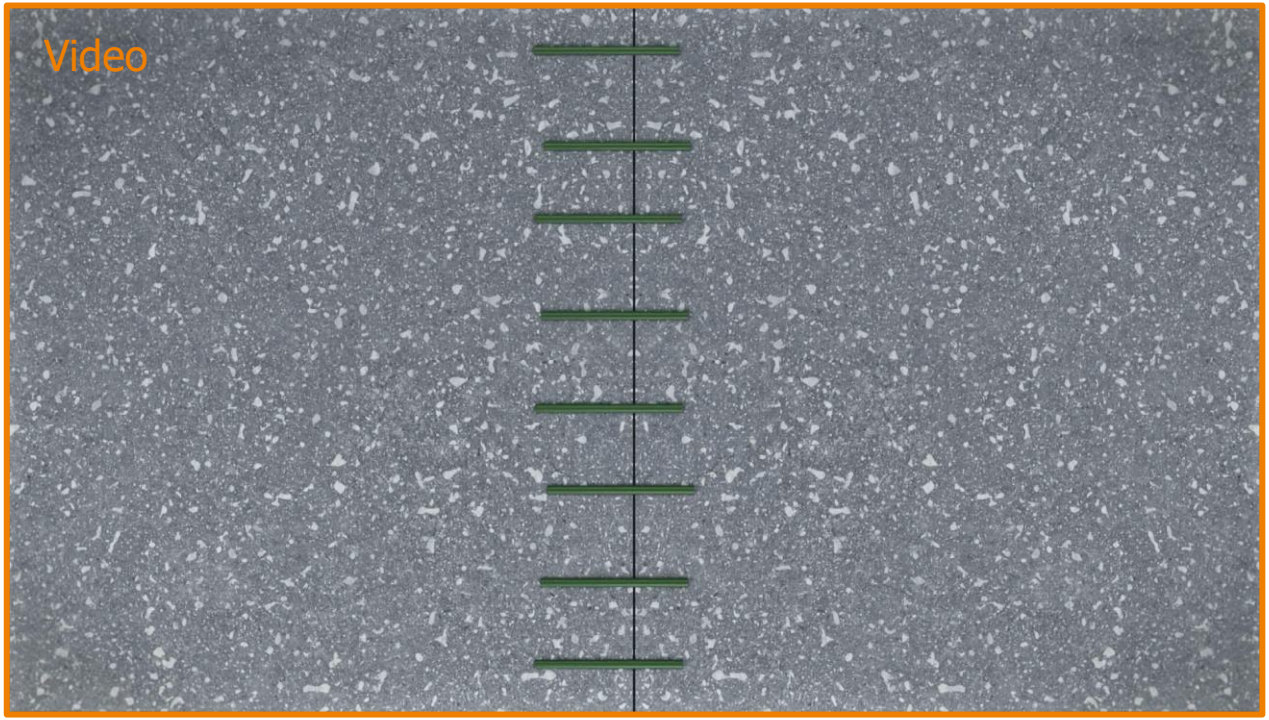
Non-destructive Testing

Dowel positions

Pavement thickness

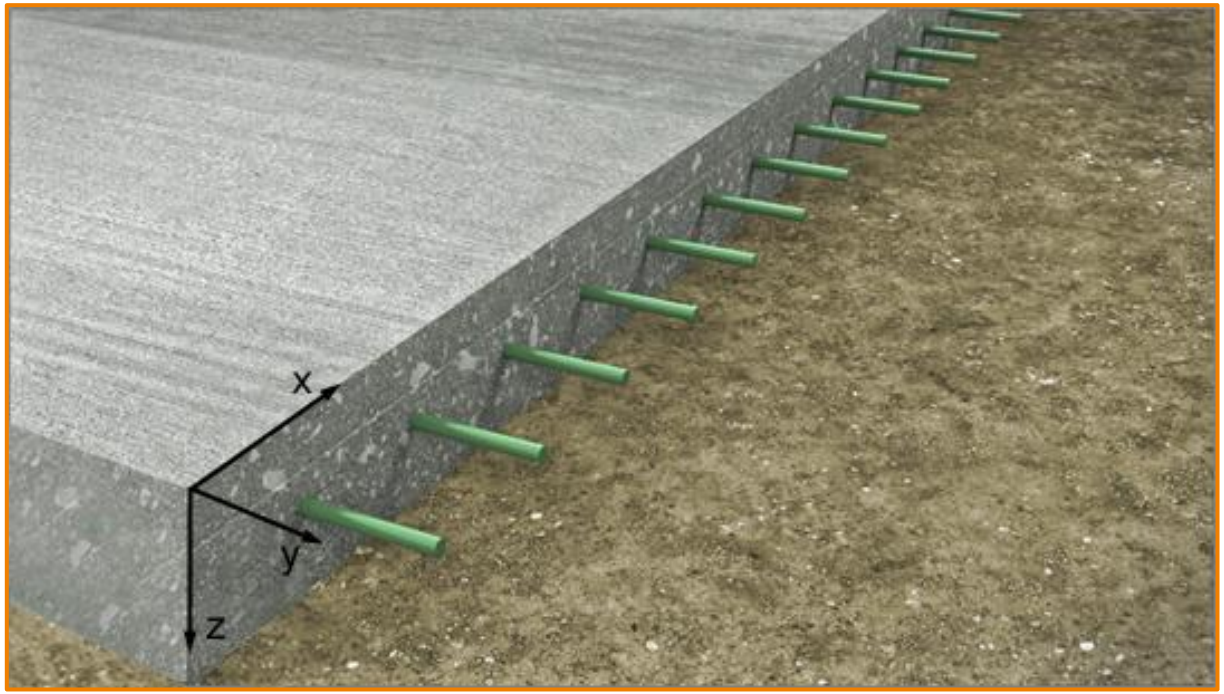
Dirk Anke, MIT Mess- und Prüftechnik GmbH, Dresden - Germany

Dowels in expansion joints



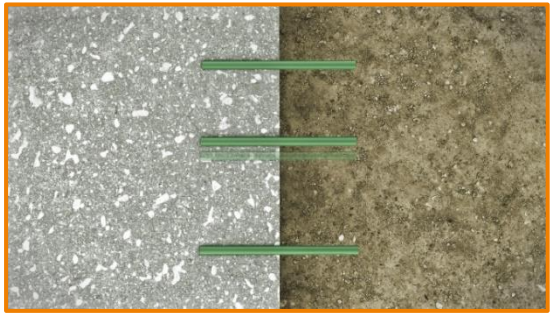
- Unhindered horizontal movement of the concrete slabs
- Load transfer between adjacent concrete slabs
- Equal heights of adjacent concrete slabs

Desired bar positions

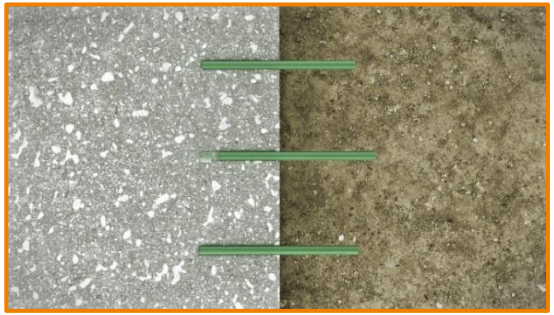


- Vertical center of slab
- Center of gravity in joint cut plane
- Perpendicular to joint cut plane

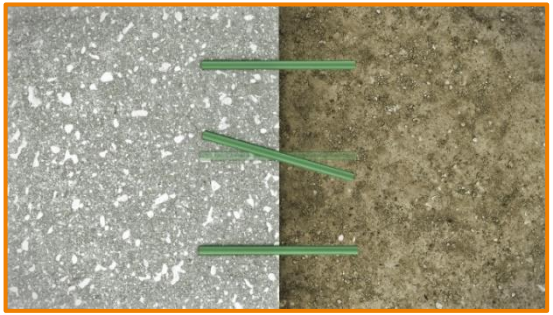
Definition of misalignments



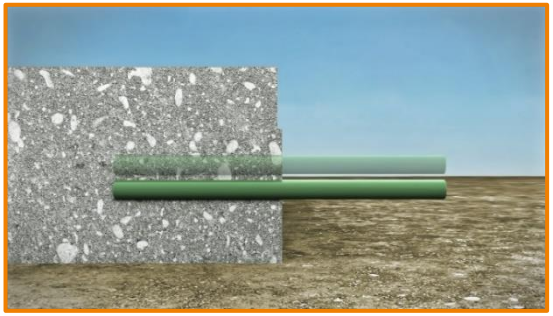
Horizontal translation



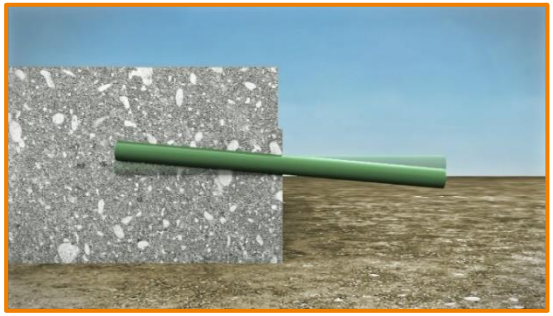
Side shift



Horizontal misalignment



Vertical translation



Vertical misalignment

Best practice

'Best practice' can mean…

performing a measurement procedure correctly

or

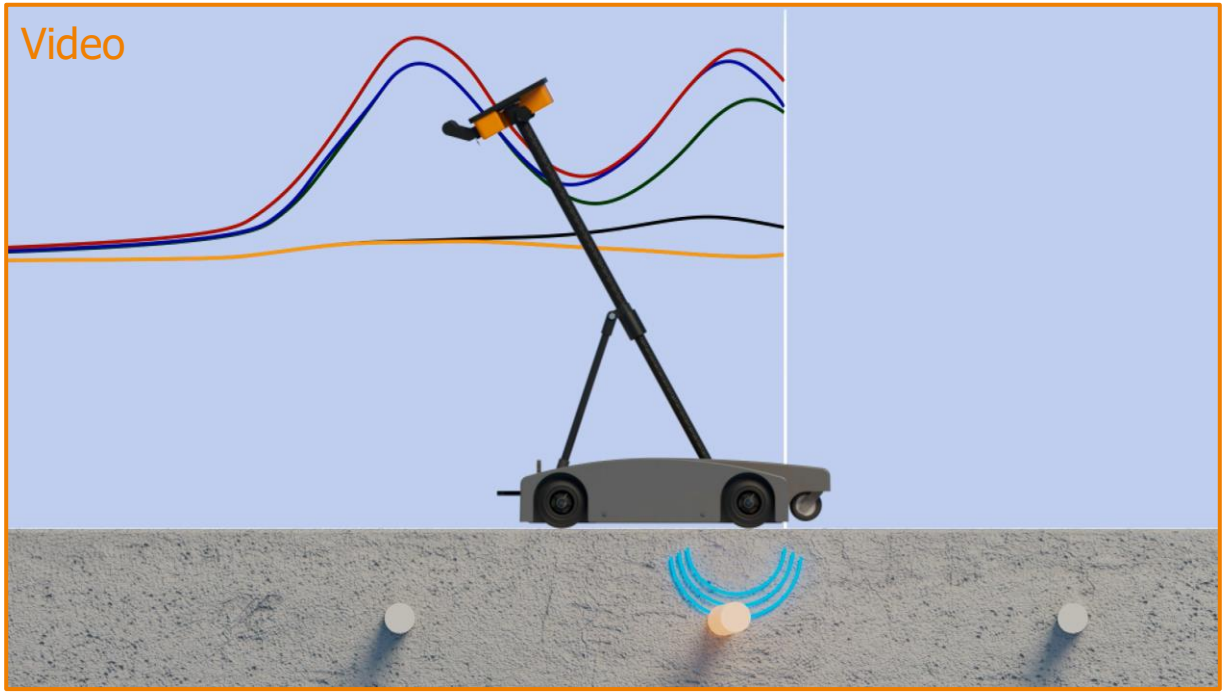
applying the most feasible measuring method

Measurement procedure

Comparison of measuring methods

	Pulse-induction method	Georadar
Constraints of measuring principle	• Susceptible to electro-magnetic influences	• Signals are influenced by moisture: Measurements only weeks after curing
Accuracy	• 4 mm for depth and misalignment • 8 mm for side shift	• 10 mm for depth and misalignment • No direct measurement of side shift
State-of-the art technology	• Specialized for dowel position measurement • Results within seconds after measurement • Automated and fast generation of reports for a series of measurements	• Flexible use for different purposes • Laborious measurement • Laborious manual data analysis that requires expert skills

Pulse-induction method



ZERSTÖRUNGSFREIE MESS- UND PRÜFTECHNIK

HOW TO MEASURE?

ZERSTÖRUNGSFREIE MESS- UND PRÜFTECHNIK

WHY MEASURE?

Best practice…

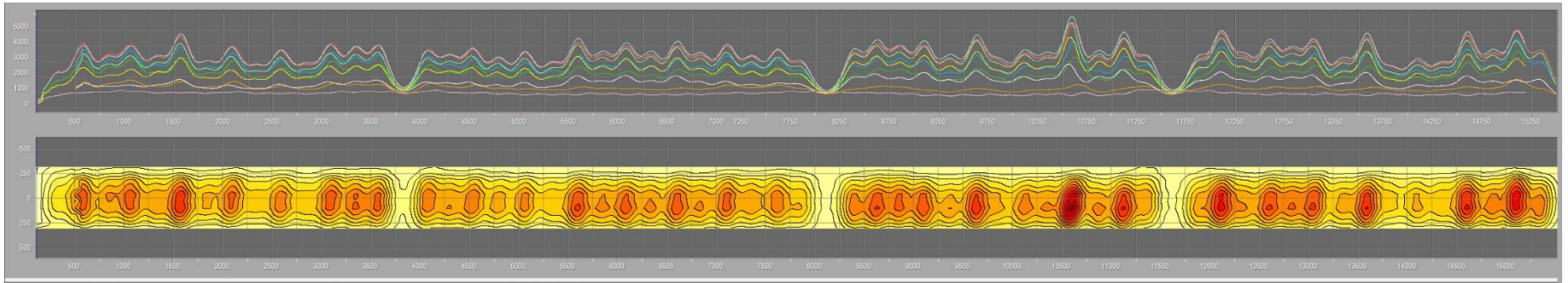
Two hypotheses we encounter:

- “The dowels are definitely lined up in a row.”
- “The dowels have nothing to do with the damage to the surface.”

Actual dowel bar positions

ZERSTÖRUNGSFREIE MESS- UND PRÜFTECHNIK

Case study 1: Depth fluctuations and great depths

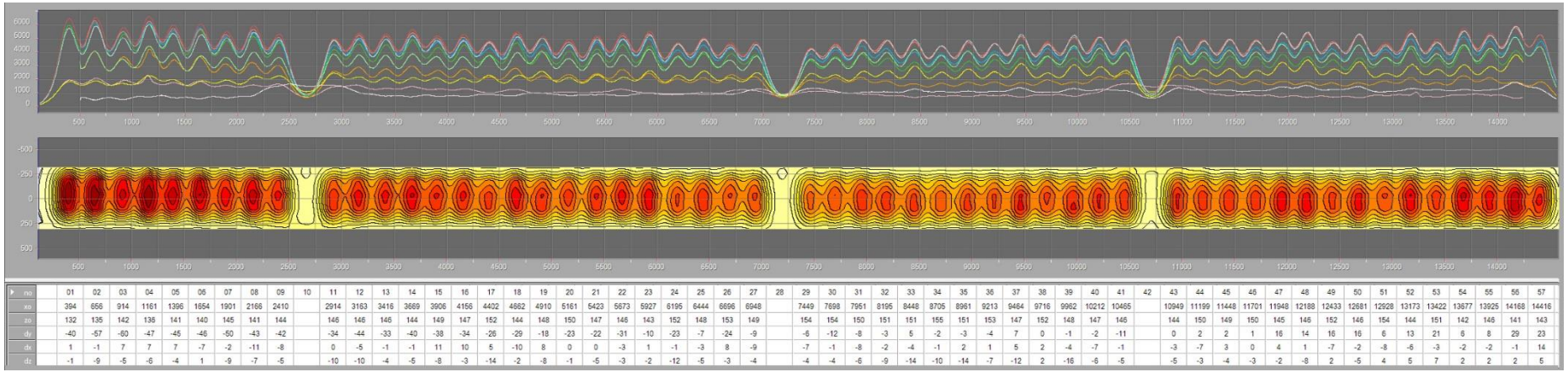


no	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61
xo	318	579	841	1074	1334	1578	1846	2097	2346	2594	2844	3097	3347	3595		4063	4302	4545	4805	5070	5340	5602	5853	6095	6342	6607	6850	7111	7362	7616	7874		8375	8630	8864	9107	9372	9634	9864	10129	10359	10615	10867	11128	11378		11875	12120	12363	12608	12837	13068	13343	13598	13836	14093	14350	14607	14865	15103	15365
zo	186	153	173	160	175	151	180	161	186	166	188	159	164	158		159	176	165	175	166	181	156	172	162	171	159	172	160	174	167	177		165	161	162	160	175	155	180	170	175	138	170	153	169		173	151	176	159	169	157	177	152	192	179	184	150	170	148	161
dy	33	18	25	30	24	25	21	24	9	34	12	37	29	29		15	24	28	23	46	37	39	40	51	35	72	33	34	30	30	17		41	39	64	52	71	52	61	48	40	61	100	70	37		72	54	33	43	52	50	32	48	31	39	20	50	25	35	21
dx	12	-2	9	3	-3	10	22	25	24	18	7	22	9	14		21	17	37	33	17	3	15	18	14	7	17	18	14	7	1	21		-10	11	10	4	10	3	10	25	22	37	-5	9	16		5	10	16	24	19	27	13	17	-3	-9	2	3	8	7	17
dz	8	4	7	7	-8	-5	1	3	-13	-4	-16	7	-5	-3		-2	-7	0	-10	-1	1	-9	-7	-8	-13	-1	-12	-2	-3	0	-10		-10	-11	7	-11	-15	-8	2	-9	-7	-7	-11	-8	3		-5	2	-11	-7	1	1	-12	-10	3	-5	-11	-3	-19	4	-20

Actual dowel bar positions

ZERSTÖRUNGSFREIE MESS- UND PRÜFTECHNIK

Case study 1: Correction of the installation process after the measurement



no	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57
xo	394	656	914	1161	1396	1654	1901	2166	2410		2914	3163	3416	3669	3906	4156	4402	4662	4910	5161	5423	5673	5927	6195	6444	6696	6948		7449	7698	7951	8195	8448	8705	8961	9213	9464	9716	9962	10212	10465		10949	11199	11448	11701	11948	12188	12433	12681	12928	13173	13422	13677	13925	14168	14416
zo	132	135	142	136	141	140	145	141	144		146	146	146	144	149	147	152	144	148	150	147	146	143	152	148	153	149		154	154	150	151	151	155	151	153	147	152	148	147	146		144	150	149	150	145	146	152	146	154	144	151	142	146	141	143
dy	-40	-57	-60	-47	-45	-46	-50	-43	-42		-34	-44	-33	-40	-38	-34	-26	-29	-18	-23	-22	-31	-10	-23	-7	-24	-9		-6	-12	-8	-3	5	-2	-3	-4	7	0	-1	-2	-11		0	2	2	1	16	14	16	16	6	13	21	6	8	29	23
dx	1	-1	7	7	7	-7	-2	-11	-8		0	-5	-1	-1	11	10	5	-10	8	0	0	-3	1	-1	-3	8	-9		-7	-1	-8	-2	-4	-1	2	1	5	2	-4	-7	-1		-3	-7	3	0	4	1	-7	-2	-8	-6	-3	-2	-2	-1	14
dz	-1	-9	-5	-6	-4	1	-9	-7	-5		-10	-10	-4	-5	-8	-3	-14	-2	-8	-1	-5	-3	-2	-12	-5	-3	-4		-4	-4	-6	-9	-14	-10	-14	-7	-12	2	-16	-6	-5		-5	-3	-4	-3	-2	-8	2	-5	4	5	7	2	2	2	5

Actual dowel bar positions

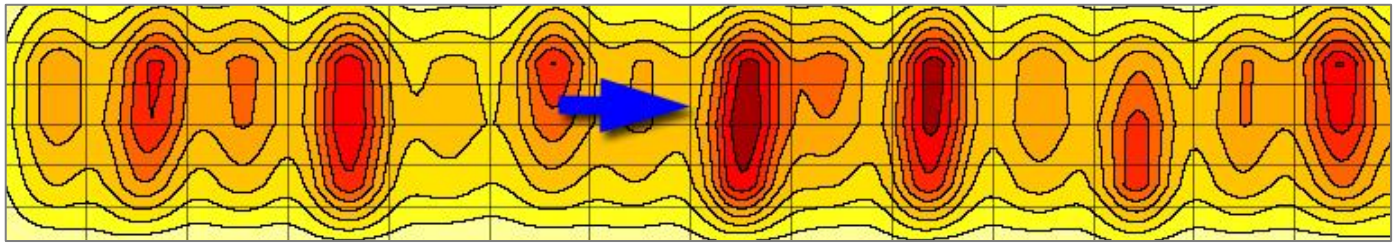
ZERSTÖRUNGSFREIE MESS- UND PRÜFTECHNIK

Case study 2: Comparative measurements in fresh concrete

Actual dowel bar positions

Case study 2: Measurement right after the paving

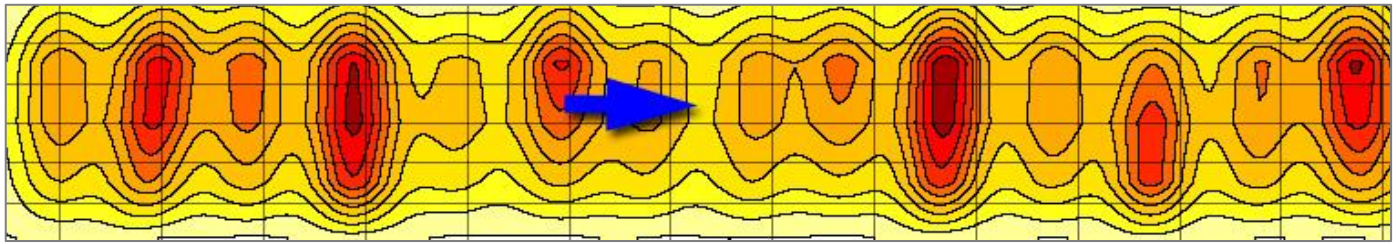
Signal chart



Actual dowel bar positions

Case study 2: Measurement 6 hours later

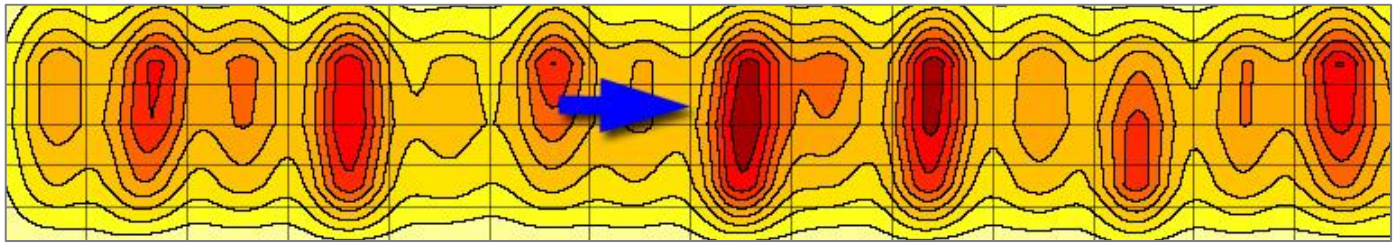
Signal chart



Actual dowel bar positions

Case study 2: Measurement right after the paving

Signal chart

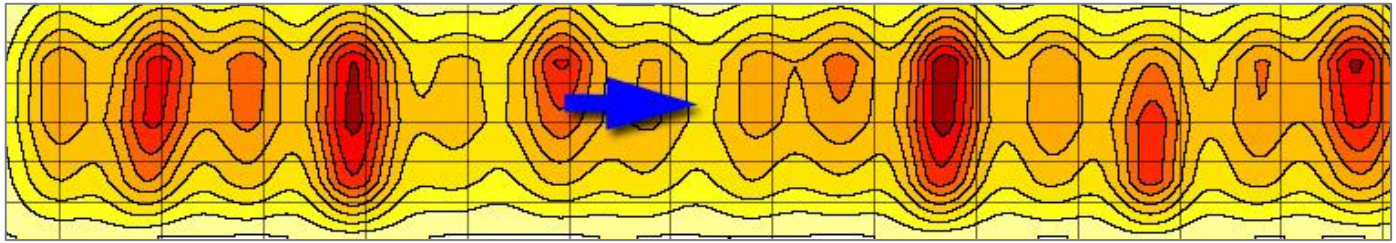


Actual dowel bar positions

Case study 2: Measurement 6 hours later

Comparison (before/after)

Signal chart



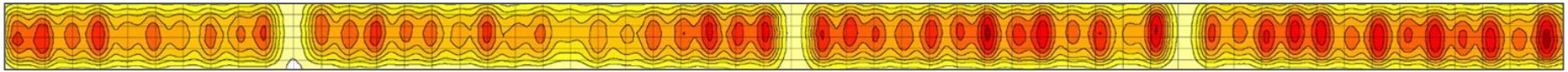
Depth	-1	-1	0	-1	-2	-1	-1	-34	-2	-2	-2	-2	-3	-3
Vertical misalignment	-1	-1	-1	0	-1	0	-1	-19	0	0	-1	-1	-2	-1

Actual dowel bar positions

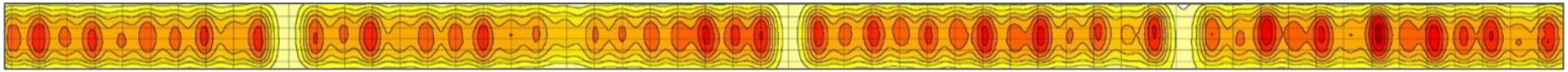
ZERSTÖRUNGSFREIE MESS- UND PRÜFTECHNIK

Case study 3: repeating patterns in neighboring joints

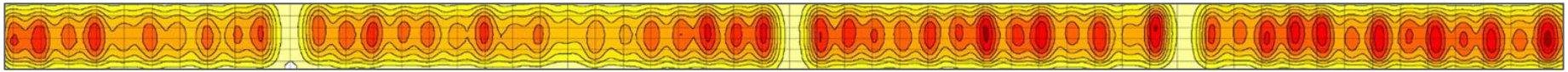
Joint 1



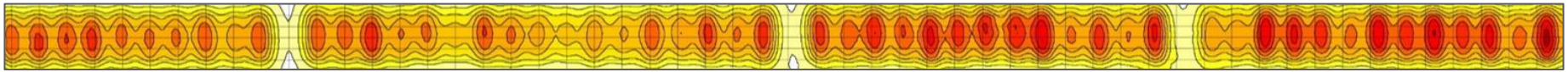
Joint 2



Joint 3



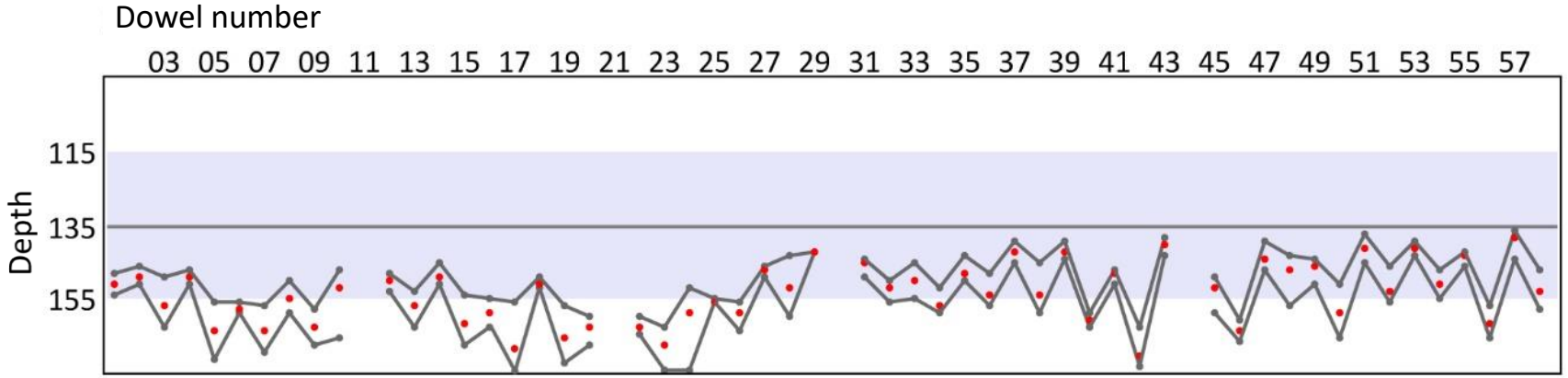
Joint 4



Actual dowel bar positions

ZERSTÖRUNGSFREIE MESS- UND PRÜFTECHNIK

Case study 3: repeating patterns - statistics on ten joints



Permissible depth: 115 mm - 135 mm
Statistical values: minimum, maximum, mean value

Actual dowel bar positions

ZERSTÖRUNGSFREIE MESS- UND PRÜFTECHNIK

Case study 4: Side shift due to incorrect joint cut

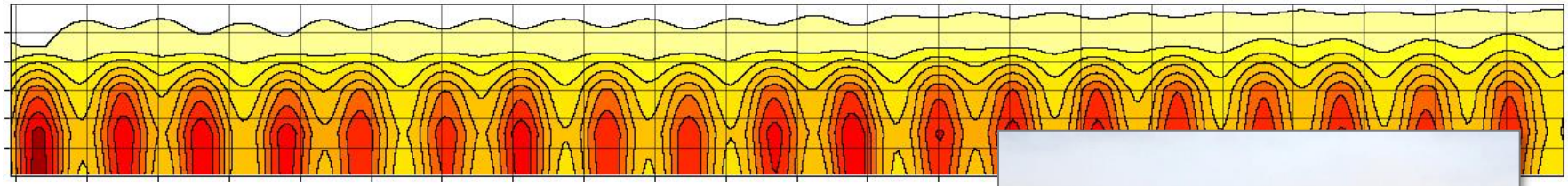
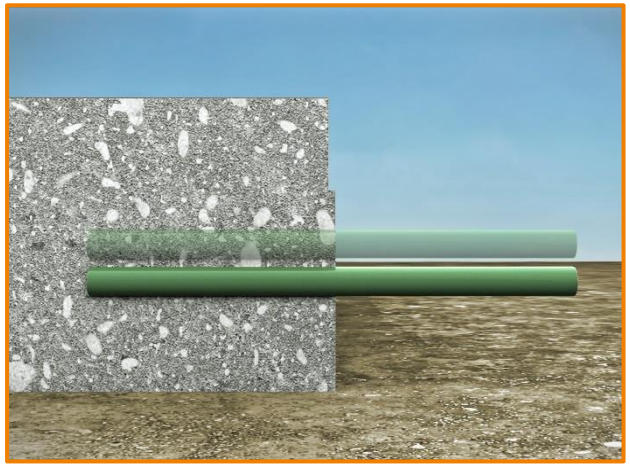


Figure 1

Effects of misalignments on the road surface

Road damage due to depth deviation



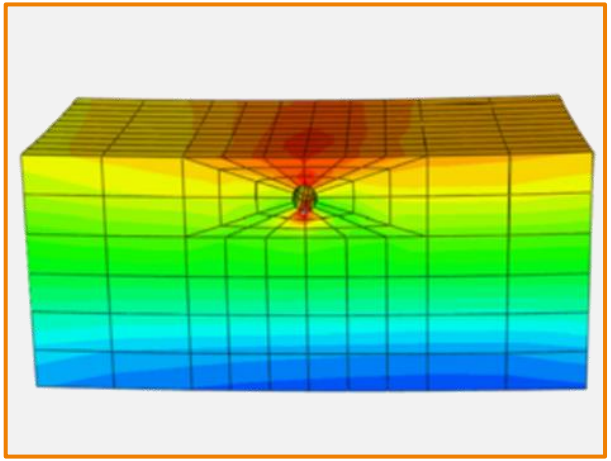
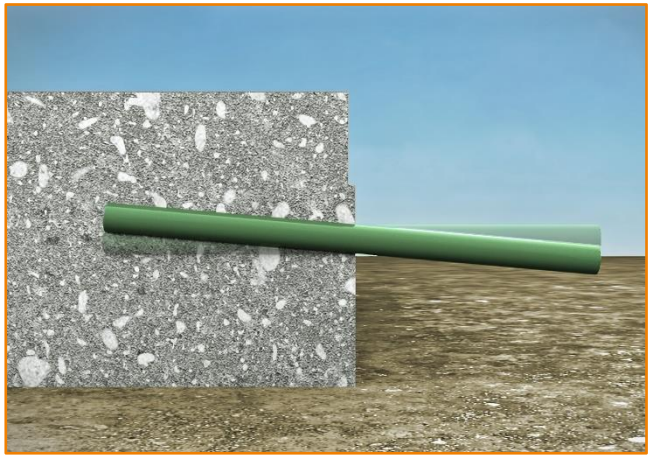


Figure 2

Figure 3

Effects of misalignments on the road surface

Road damage due to misaligned dowels



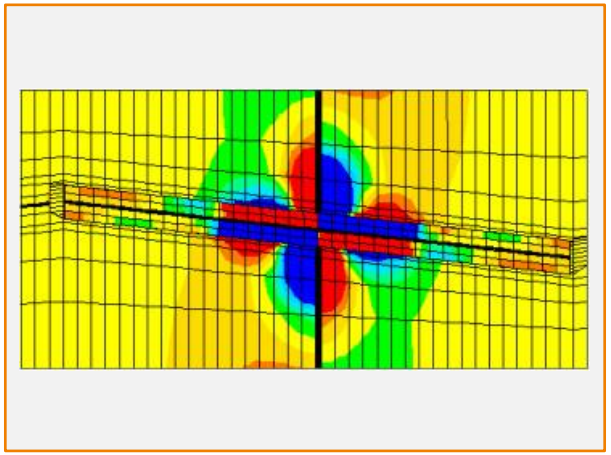


Figure 4

Figure 5

Effects of misalignments on the road surface

Road damage due to shifted basket positions

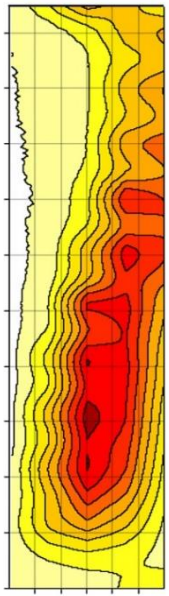


Figure 6

Effects of misalignments on the road surface

ZERSTÖRUNGSFREIE MESS- UND PRÜFTECHNIK

Research programs in the USA (2009 - 2020)

Field studies
2300 Joints in
17 states

Figure 7

Laboratory tests
Tensile tests
Shear tests

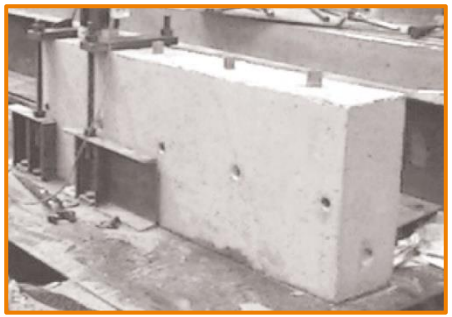


Figure 8

Theoretical models
Finite elements analysis

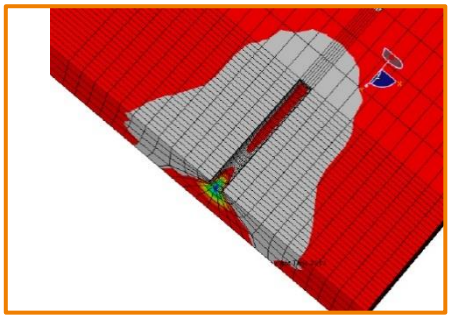


Figure 9

Non-destructive Testing

Pavement thickness

ZERSTÖRUNGSFREIE MESS- UND PRÜFTECHNIK

HOW TO MEASURE?

ZERSTÖRUNGSFREIE MESS- UND PRÜFTECHNIK

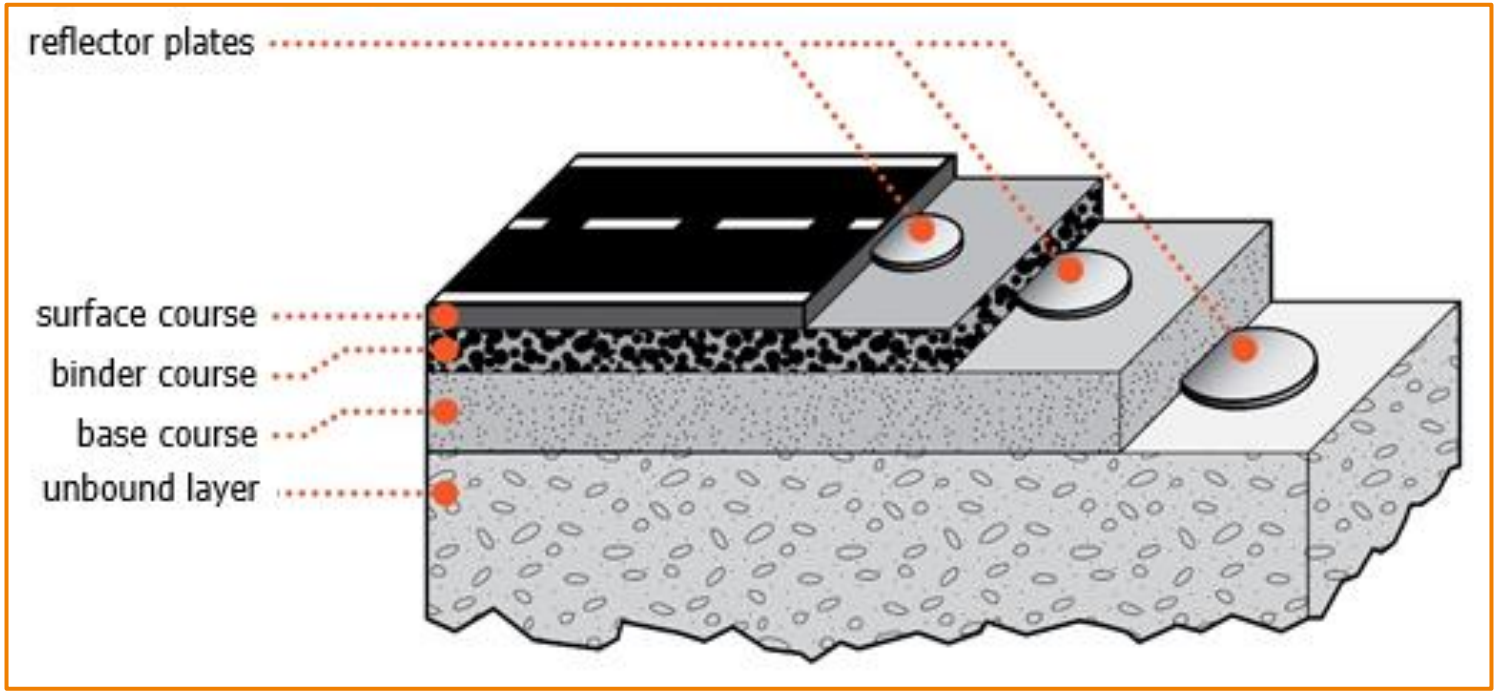
WHY MEASURE?

Electromagnetic method for thickness measurement

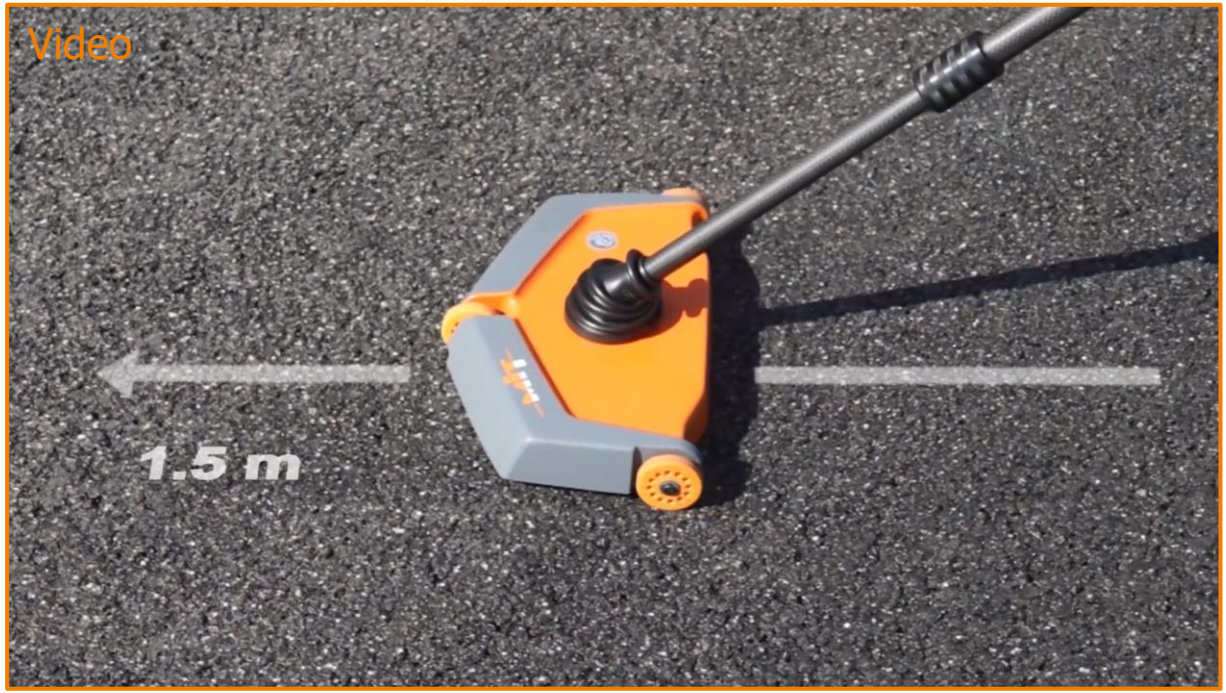
- Non-destructive
- Fast measurements
- Accurate and repeatable results
- Feasible on asphalt and concrete
- Complying with international standards

  (EN 12697-36, ASTM E3209)

Antipoles

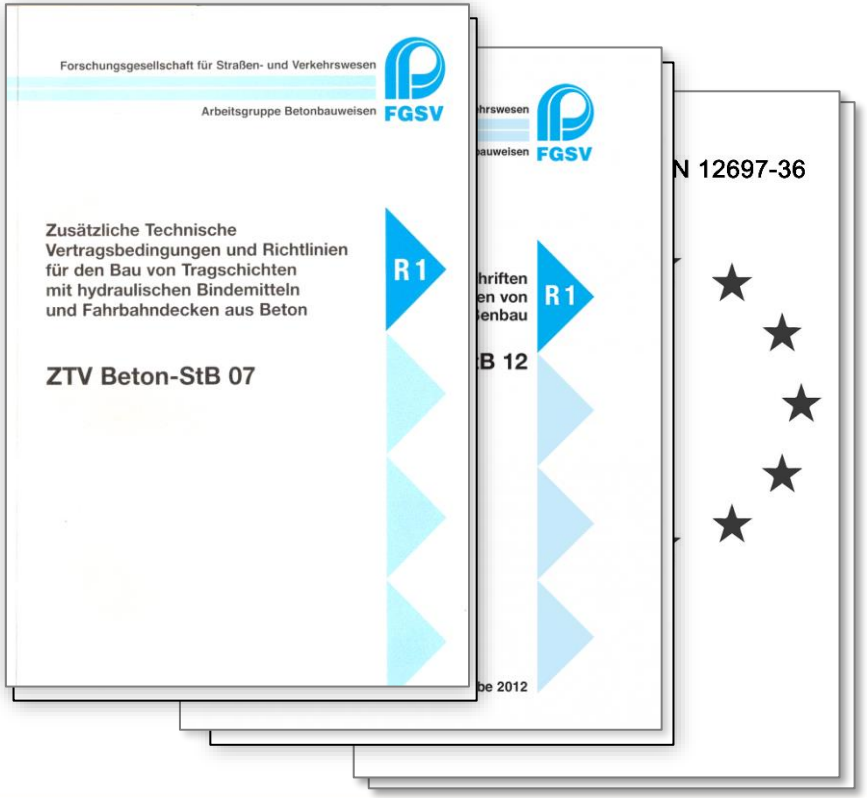

reflector plates
surface course
binder course
base course
unbound layer

Measuring procedure



The simple measurement procedure takes only a few seconds and offers immediate and accurate results.

Current practice in Germany/Europe



Standards exist in Germany for asphalt (in accordance with European standard EN 12697-36) and concrete.

Up to now, road pavement thickness in Germany has mainly been measured for asphalt and to a lesser extent for concrete.

The scope of application depends on the requirements of the respective standards.

Concrete pavement thickness

Relevance for longevity of the road

In addition to the splitting tensile strength, the pavement thickness is a crucial factor for the service life of the road.

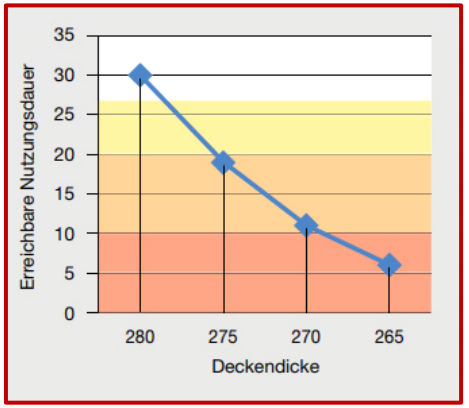
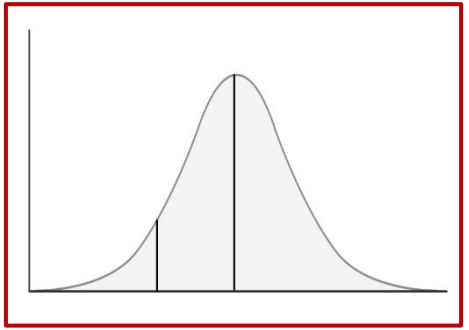


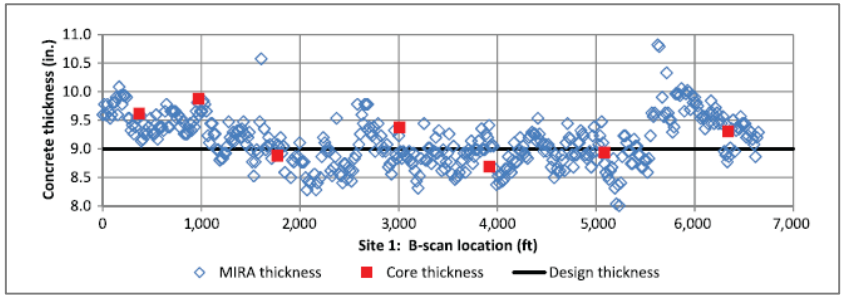
Figure 10

Determining the thickness profile of the road

The basis for the requirement of the standard for concrete roads is the assumption that statistical parameters of normally distributed thicknesses can be determined on the basis of a few values.



Study on the density of thickness measurements



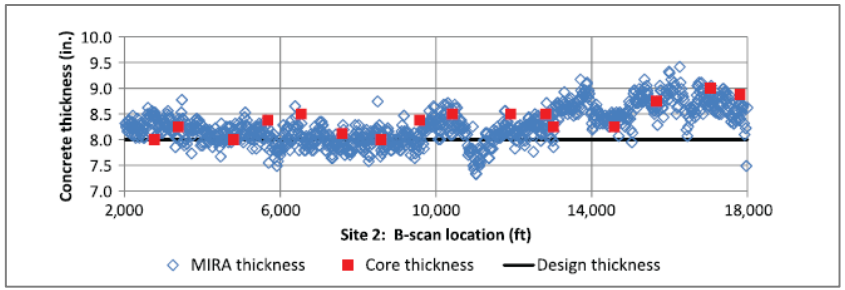


Figure 11

Determining the thickness profile of the road based on drill cores taken at specific points is only possible to a limited extent.

Scientific studies recommend more closely meshed measurements for determining the average concrete thickness and local outliers.

Non-destructive measuring methods are well suited for this.

Thank you for your attention!

Image sources

Fig. 1	Overstreet M, Public domain, via Wikimedia Commons [online] https://commons.wikimedia.org/wiki/File:Concrete_saw.jpg, accessed 26/02/2024
Fig. 2:	Seo Y., Kim S. (2013): "Longitudinal Cracking at Transverse Joints Caused by Dowel Bars in Jointed Concrete Pavements", KSCE Journal of Civil Engineering 2013, 17 (2): page 395 - 402
Fig. 3, 5, 6	Yaqoob S. (2024): "Concrete pavements' repair techniques and numerical assessment of dowel bar load transfer efficiency", KTH [online] https://kth.diva-portal.org/smash/get/diva2:1834639/FULLTEXT01.pdf, accessed 26/02/2024
Fig. 4	Khazanovich L. et al (2010): "Evaluation of Alignment Tolerances for Dowel Bars And Their Effect on Joint Performance", Report No. FHWA/ MDOT RC-1395, Washington D.C.
Fig. 7, 9	Snyder M. (2018): Dowel Bar Alignment: What Do We Need? What Should We Expect?, ACPA [online] https://acpa-se.org/wp-content/uploads/2018/11/2018-10-29-NCCPC-Snyder-Dowel-Alignment.pdf, accessed 26/02/2024
Fig. 8	Saxena P. et al (2009): Laboratory and Finite Element Evaluation of Joint Lockup. Transportation Research Record 2095, page 34 - 42
Fig. 10	Schmerbeck R. (2016): "Anwendung der RDO Beton im VOB-Vertrag", in "Griffig 1/2016", Düsseldorf: Verlag Bau+Technik
Fig. 11	Vancura M. et al (2013): "Concrete Pavement Thickness Variation Assessment with Cores and Nondestructive Testing Measurements", Journal of the Transportation Research Board, 2347/ page 61 – 68