Load transfer at joints for industrial floors

Where do we come from?

Traditional load transfer calculations have been based on bending and shear of steel bars or plates connecting adjacent concrete panels or, most decisively, on concrete bursting below or above those load transfer devices. The results inevitably show that the joint has a lower load capacity (often less than 40%) compared to the interior load capacity of the concrete slab.

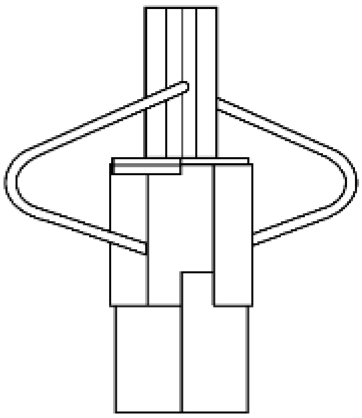
The industrial floor calculation itself is frequently controlled by load transfer at joints (usually around 40% when using load transfer systems), whereby the design values for “edge” loading of the floor slab are significantly reduced. However, this applied percentage is an assumption and, until now, this assumption was rarely checked or confirmed.

Worse still, the serviceability of joints is not surveyed at all. The result of this is repeated damage, especially for armoured jointing systems, where typically the flooring company has to repair the damage while often not being responsible for the cause.

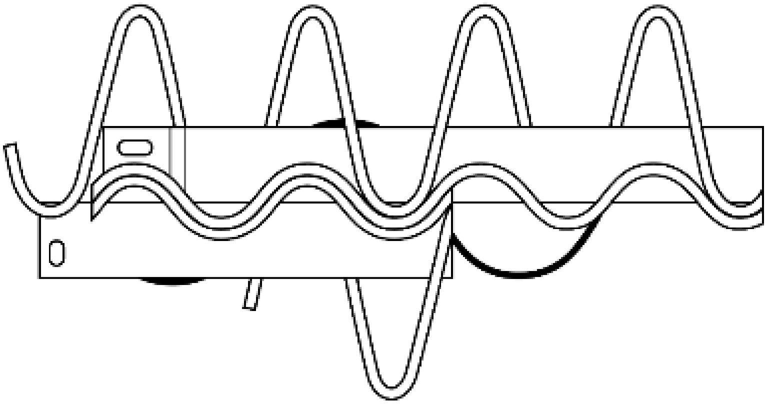
We have decided to take a step forward and to develop a system that is able to meet ultimate limit state (ULS) design requirements while ensuring service limit state (SLS) and durability.

The result: **COSINUS Slide® Joint**

Cross section



Top view



Whole body vibrations - European directive 2002/44/EC:

Ensuring serviceability means not only limiting vertical displacement and allowing horizontal movements, it is also a matter of complying with international regulations. The European directive 2002/44/EC formulates limits of exposure of workers to whole body vibrations. In this case, it concerns drivers of MHE who are exposed to vibrations during their work shift.

An independent body certifies that the Cosinus Slide® Joint complies with the limits of exposure. In this respect, several tests have been performed to check the level of acceleration that might happen with different joint types and vehicles. As a result, Cosinus Slide® joints comply with this European directive 2002/44/EC and guarantee shock and vibration free trafficking.

Load transfer not based on assumptions anymore:

Concrete Society TR34 4th edition does not recommend continuous load transfer systems due to "poor performance in service" and the described calculation model is only based on discontinued dowel systems. From TR34 3rd to TR34 4th edition the calculated load transfer capacity has been dramatically reduced (by more than 50 %) due to an "overestimation" of the concrete bursting resistance.

So what to do with a continuous load transfer system that performs outside of any guideline?

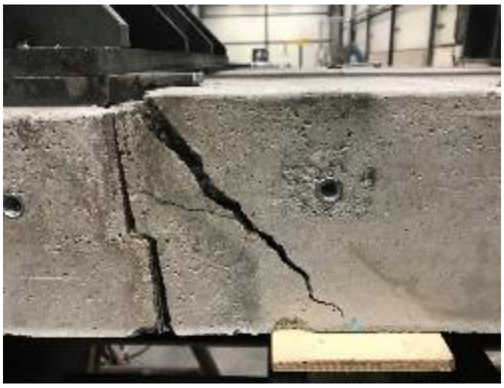
CONFIRMING PERFORMANCE BY TESTING:

In collaboration with a German engineering and construction testing company, we performed testing with a high number of specimens to make sure of obtaining reliable and correct testing data.

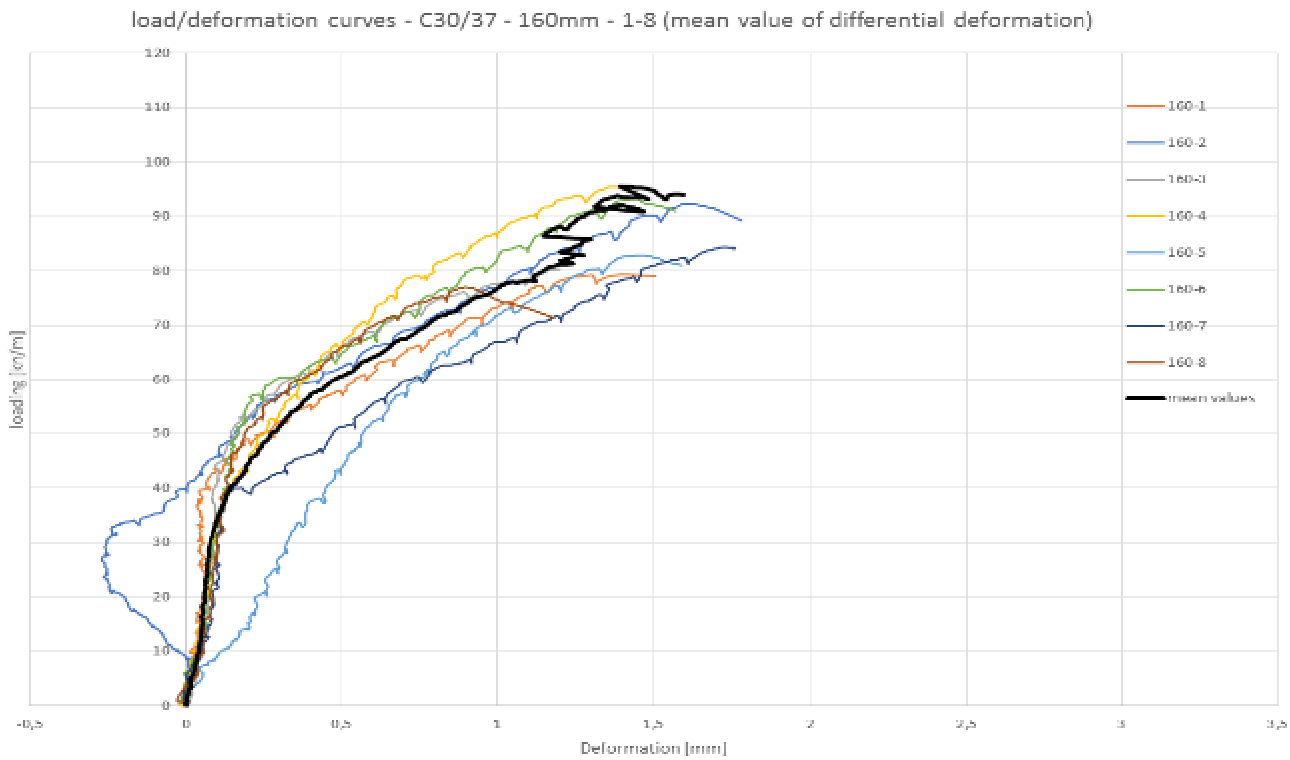
In order to allow later interpolation of results, the tests have been performed with a lower limit of C30/37 and an upper limit of C40/50 without reinforcement. Only an upper mesh has been placed to avoid bending failure of concrete before the capacity of the joint has been achieved. After numerous internal testing to optimize the product, we have started the official surveyed testing with the most popular product Cosinus Slide® 160-215 that covers slab thicknesses from 160 to 215 mm and a testing system that is very clear without leaving doubts in terms of interpretation of results:

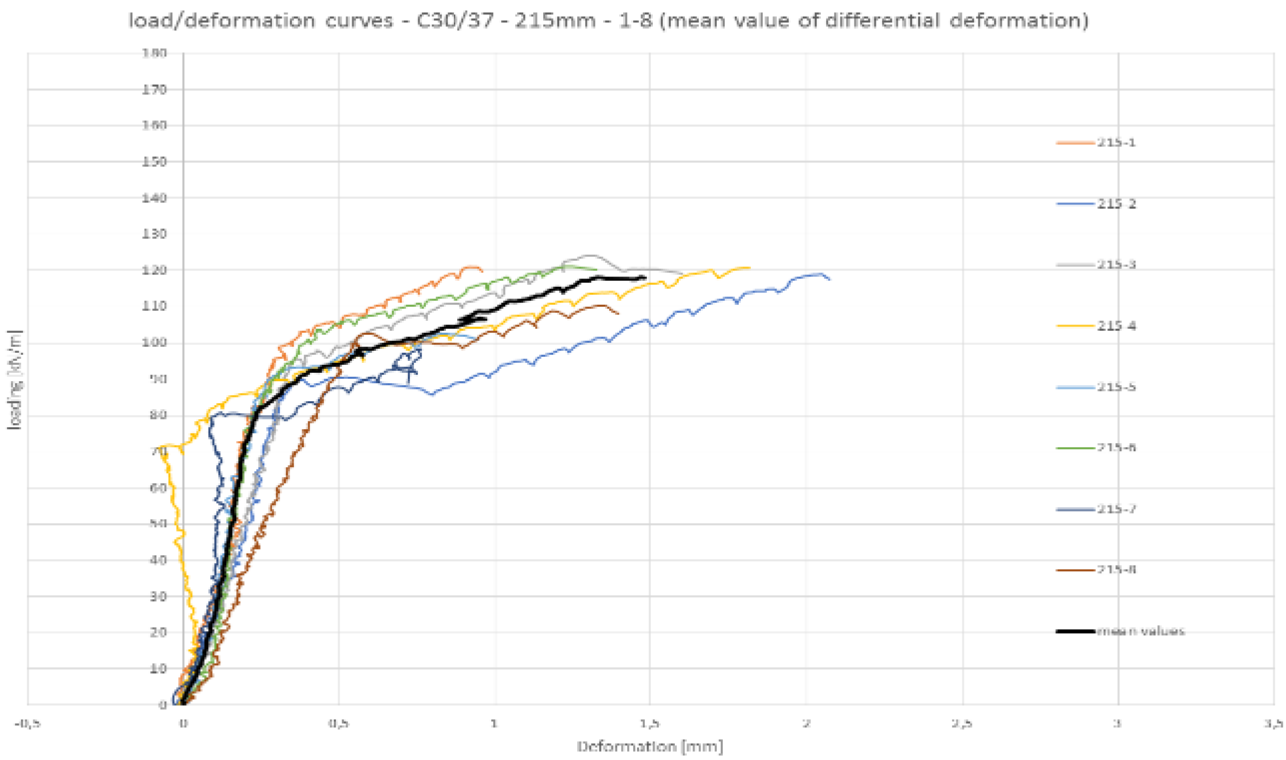
Pictures of casting:

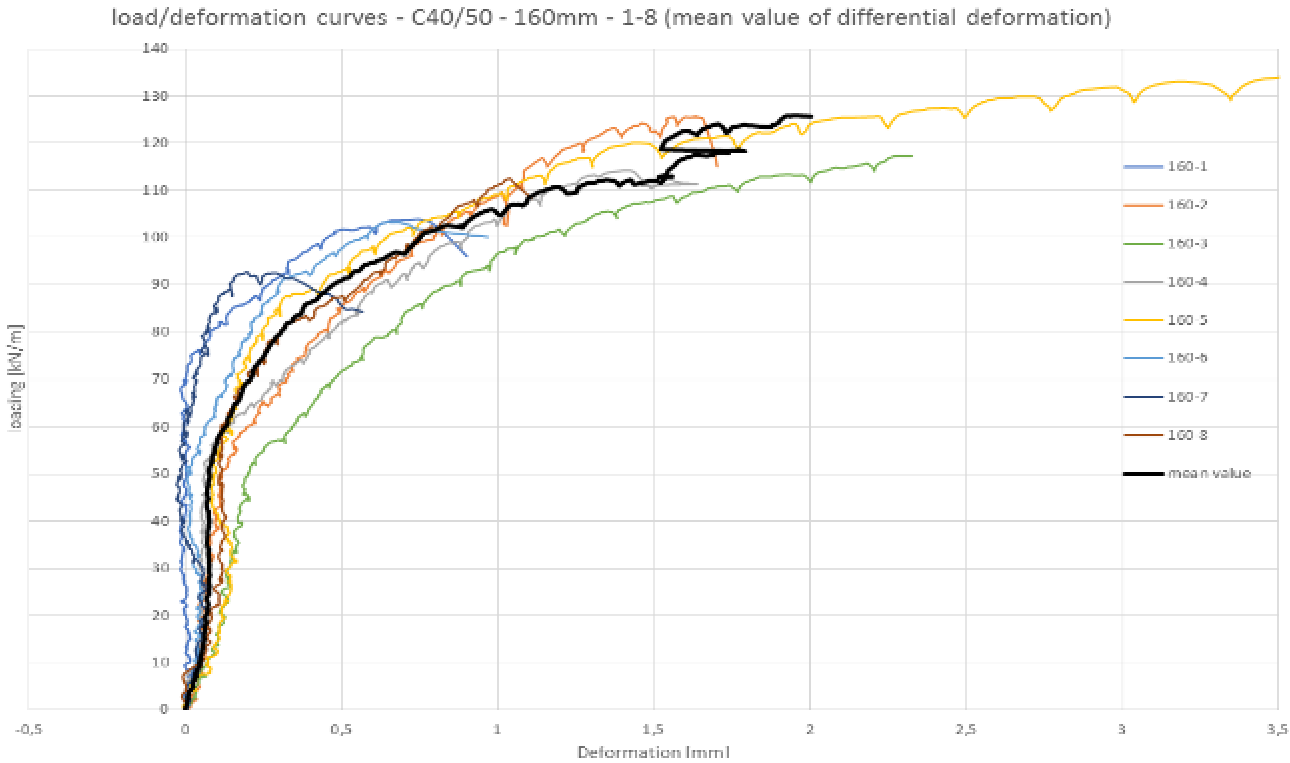
Pictures of testing:

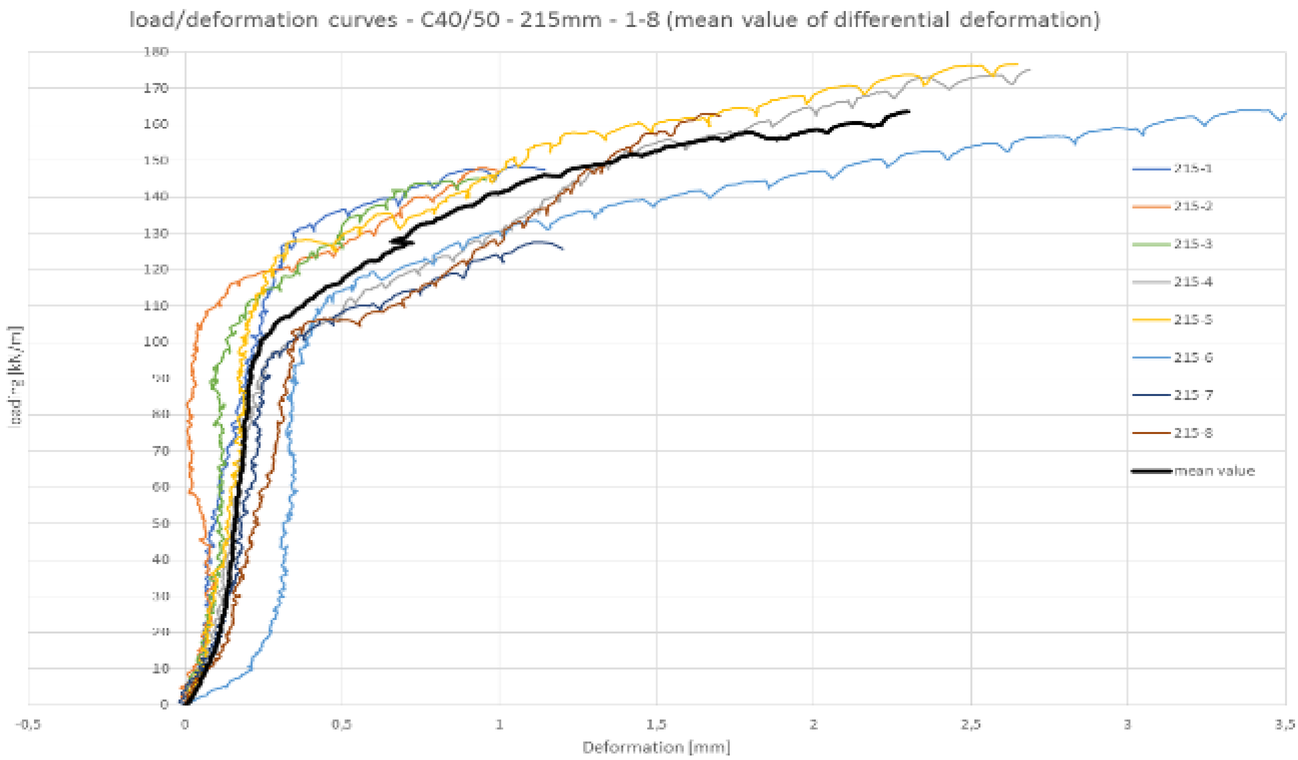


All specimens have shown the same final failure behaviour: concrete bursting behind the stirrups with very little deformation between the two joint parts and we could deduce the following load-deformation curves of eight specimens that have been tested for each concrete quality and thickness:






load/deformation curves - C40/50 - 160mm - 1-8 (mean value of differential deformation)
loading [kN/m]
Deformation [mm]
160-1
160-2
160-3
160-4
160-5
160-6
160-7
160-8
mean value


load/deformation curves - C40/50 - 215mm - 1-8 (mean value of differential deformation)
Deformation [mm]
215-1
215-2
215-3
215-4
215-5
215-6
215-7
215-8
mean value

In accordance with annex D7 of DIN EN 1990:2010-12 (Eurocode 0): Grundlagen der Tragwerks-planung, Deutsche Fassung EN 1990:2002 + A1:2005 + A1:2005/AC:2010
we have derived, under consideration of necessary statistical analyses, the following characteristic bursting resistance values for each of the performed tests:

Cosinus profil type		160-215		
concrete class		C30/37		
specimen height		160 mm		
characteristic load transfer				
specimen	loading	own w.	total load	[log]
1	79,40	3,25	82,65	4,415
2	92,40	3,25	95,65	4,561
3	80,40	3,25	83,65	4,427
4	95,50	3,25	98,75	4,593
5	82,90	3,25	86,15	4,456
6	93,20	3,25	96,45	4,569
7	84,40	3,25	87,65	4,473
8	77,10	3,25	80,35	4,386
mean value 1-8			88,91	4,485
Standart deviation 1-8			6,59961	0,078757
fractil k_n acc. EN 1990:2010-12, Tab. D1 (n=8)				2,00
characteristic value			75,71 kN/m	75,75 kN/m
characteristic value: $V_{Rk,c}$ =				**75,71 kN/m**
desing value (γ_c = 1,5): $V_{Rd,c}$ =				**50,48 kN/m**

Cosinus profil type			160-215	
concrete class			C30/37	
specimen height			215 mm	
characteristic load transfer				
specimen	loading	own w.	total load	[log]
1	121,00	3,441	124,44	4,824
2	118,90	3,441	122,34	4,807
3	124,00	3,441	127,44	4,848
4	120,70	3,441	124,14	4,821
5	102,50	3,441	105,94	4,663
6	121,10	3,441	124,54	4,825
7	98,30	3,441	101,74	4,622
8	110,10	3,441	113,54	4,732
mean value 1-8			118,02	4,768
Standart deviation 1-8			9,08030	0,08498127
fractil k_n acc. EN 1990:2010-12, Tab. D1 (n=8)				2,00
characteristic value			99,86 kN/m	99,26 kN/m
characteristic value: $V_{Rk,c}$ =				**99,26 kN/m**
desing value (γ_c = 1,5): $V_{Rd,c}$ =				**66,18 kN/m**

Cosinus profil type	160-215
concrete class	C40/50
specimen height	160 mm

characteristic load transfer

specimen	loading	own w.	total load	[log]
1	104,00	3,252	107,25	4,6752
2	126,00	3,252	129,25	4,8618
3	117,00	3,252	120,25	4,7896
4	115,00	3,252	118,25	4,7728
5	103,00	3,252	106,25	4,6658
6	120,00	3,252	123,25	4,8142
7	112,00	3,252	115,25	4,7471
8	93,00	3,252	96,25	4,5670
mean value 1-8			114,50	4,74
Standart deviation 1-8			9,97184	0,095229
fractil k_n acc. EN 1990:2010-12, Tab. D1 (n=8)				2,00
characteristic value			94,56 kN/m	94,28 kN/m

characteristic value: $V_{Rk,c}$ = **94,28 kN/m**

desing value (γ_c = 1,5): $V_{Rd,c}$ = **62,85 kN/m**

nv. HENGELHOEF CONCRETE JOINTS ▪ Hengelhoefstraat 158 ▪ B - 3600 Genk
tel +32-89.32.39.80 ▪ fax +32-89.32.39.88 ▪ www.hcjoints.be ▪ info@hcjoints.be

Cosinus profil type	160-215
concrete class	C40/50
specimen height	215 mm

characteristic load transfer

specimen	loading	own w.	total load	[log]
1	150,00	3,441	153,44	5,0333
2	148,10	3,441	151,54	5,0209
3	145,10	3,441	148,54	5,0009
4	175,20	3,441	178,64	5,1854
5	176,60	3,441	180,04	5,1932
6	183,60	3,441	187,04	5,2313
7	127,50	3,441	130,94	4,8748
8	163,10	3,441	166,54	5,1152
mean value 1-8			162,09	5,08
Standart deviation 1-8			17,95292	0,12077028
fractil k_n acc. EN 1990:2010-12, Tab. D1 (n=8)				2,00
characteristic value			126,19 kN/m	126,51 kN/m

characteristic value: $V_{Rk,c}$ = **126,19 kN/m**

desing value (γ_c = 1,5): $V_{Rd,c}$ = **84,12 kN/m**

Development of calculation model:

Testing and analysis has shown a clear set of results considering concrete strength and element thickness.

This allows to us to use the following formula (initially based on EN 1992) to calculate the minimum load transfer capacity at ultimate limit state (ULS):

$$\boxed{V_{Rd,c} = V_{min} = 0{,}0525 \ / \ \gamma_c \ . \ k^{3/2} \ . \ f_{ck}^{1/2} \ . \ 0{,}80 \ . \ h \ / \ 1{,}4 \ [kN/m]}$$

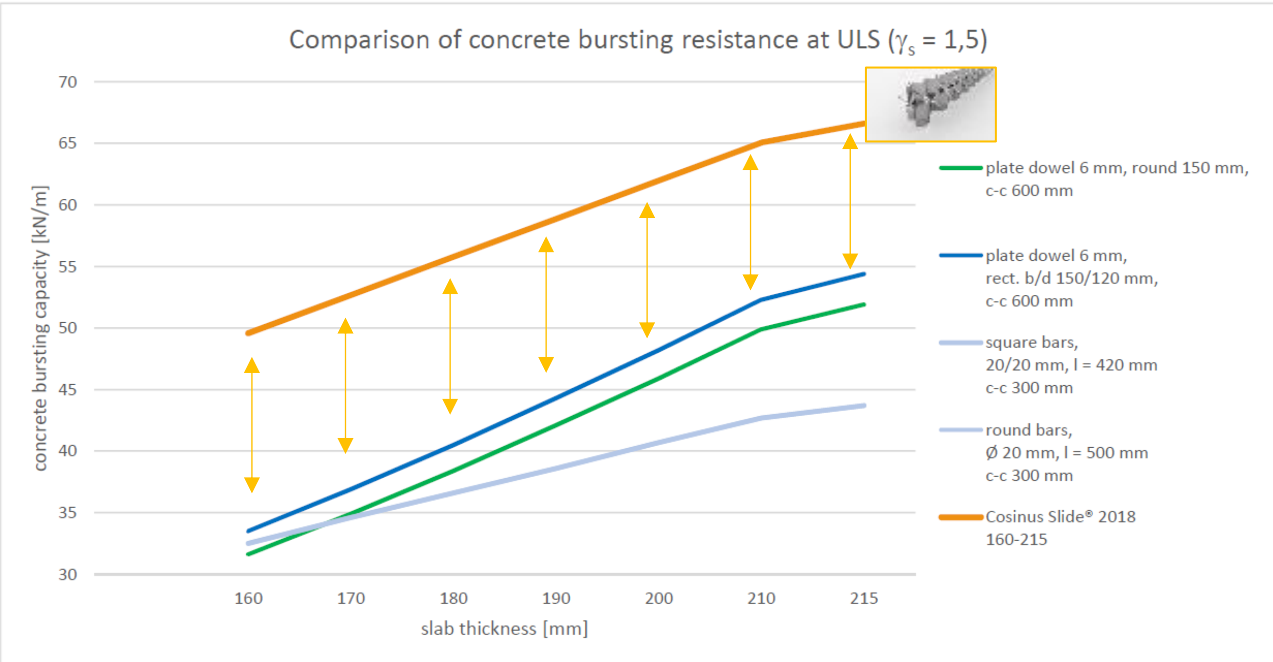
with:
- γ_c = partial safety factor for concrete
- k = influence of section with $k = 1 + (200 / d)^{0,5}$
- f_{ck} = characteristic concrete compressiv strenght [N/mm²]
- 0,80 = correction factor for loss of upper concrete cover and mean variation
- h = slab thickness [mm]
- 1,4 = reduction factor for edge loading

<u>Comparison:</u>

Comparison of the most common dowel systems, calculated according TR34 4th edition with the Cosinus Slide® (calculated on earlier mentioned formula based on testing and simulation results):

concrete bursting resistance, dowels acc. TR34 4th edition vs. Cosinus Slide® testing results.
Resluts at ULS (γ_c = 1,5) in [kN/m], concrete C30/37, calculated from the center of section, joint opening 15 mm

slab thickness	dowel / joint type				
[mm]	plate dowel 6 mm, round 150 mm, c-c 600 mm	plate dowel 6 mm, rect. b/d 150/120 mm, c-c 600 mm	square bars, 20/20 mm, l = 420 mm c-c 300 mm	round bars, Ø 20 mm, l = 500 mm c-c 300 mm	Cosinus Slide® 2018 160-215
160	31,6	33,5	32,5	32,5	49,6
170	34,9	36,9	34,6	34,6	52,7
180	38,4	40,5	36,6	36,6	55,8
190	42,1	44,3	38,6	38,6	58,9
200	45,9	48,2	40,7	40,7	62,0
210	49,9	52,3	42,7	42,7	65,1
215	51,9	54,4	43,7	43,7	66,6



Conclusion:

If you want to utilize the whole performance your industrial floor can provide, use the Cosinus Slide® joint.

Due to the high-performance level of Cosinus Slide® we can not only guarantee the best performance and durability, but we can optimize your floor design where "edge" loading at the joint is the controlling parameter.

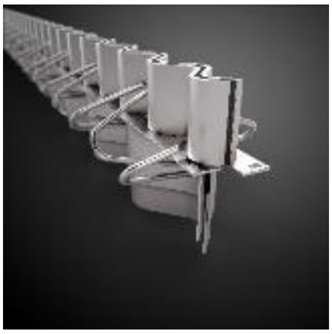
The most critical load cases at the edges can be justified and the design optimization can consist of:

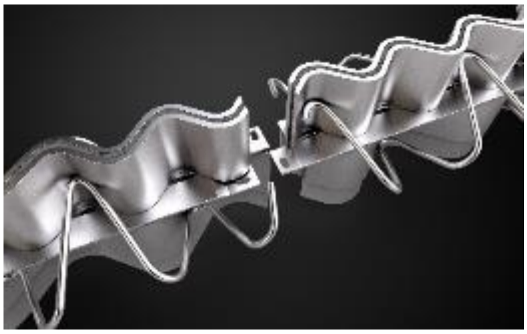
- reduction of slab thickness
- reduction of reinforcement
- placing racking legs or other punctual loads immediately at the joint

With Cosinus Slide® long-term durability can be obtained as vibration and shock free forklift traffic becomes possible.

At SLS we can guarantee the necessary joint stability. ACI 360 for example requires 0,01" (0,25 mm) joint stability at SLS for trafficked areas with small hard wheels.

All those technical facts together with the new Cosinus Slide® joint connection system, that allow a very precise and faster installation makes it probably to best jointing system worldwide.





Outlook:

"Innovation and R&D are the key words in our company." – This was not only a marketing gimmick

Several years of R&D made us understand the principal of Cosinus Slide® and its behaviour in concrete.

Nevertheless, the mission of providing complete data to analyse and design the industrial floor including the joints at ULS and SLS is not yet at its end.

Initial tests have shown that – contrary to the statement in TR34 4^{th} edition – steel fibres contribute to concrete bursting resistance. The influence of fibres and other reinforcement types will certainly be the focus for future R&D projects.

In the meantime we can – based on the above research results – provide complete load transfer design checks including technical support in order to help you to optimize your industrial flooring project!