Air void distribution in concrete studied using X-ray/neutron tomographic imaging and optical reflection imaging

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Purpose of research

Quantitative description of air void distribution in air-entrained concrete to validate the standard approach to freeze-thaw durability (case study).

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Range of investigation

Three measuring techniques:

- neutron imaging → Budapest Neutron Centre, Hungary
- X-ray microtomography → Yonsei University, Korea
- optical microscopy → IPPT PAN, Poland

Air-void system parameters significant for freeze-thaw durability:

(A) Powers spacing factor = model description the void-to-void proximity (the distance distribution between air voids)

(B) the air-void size distribution (small voids more important)

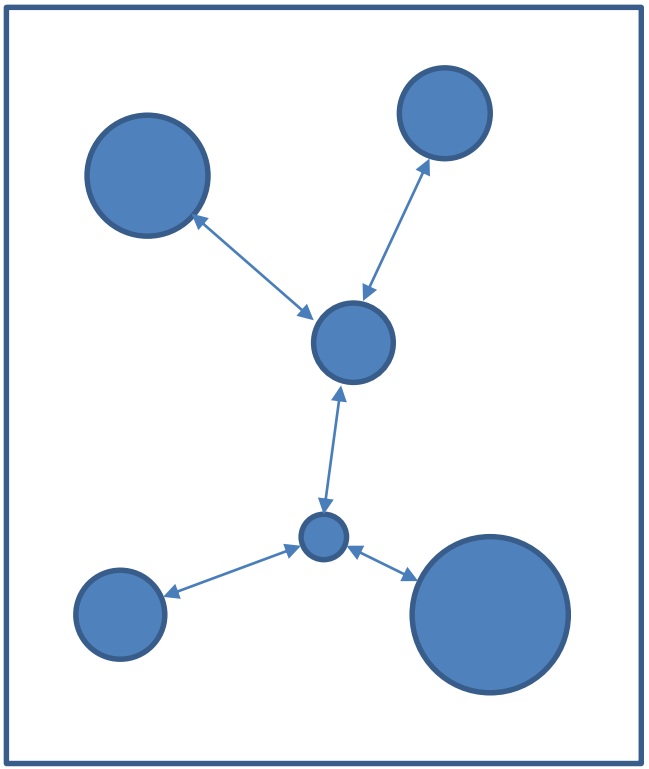
(C) the total content of voids (not too much to reduce the strength)

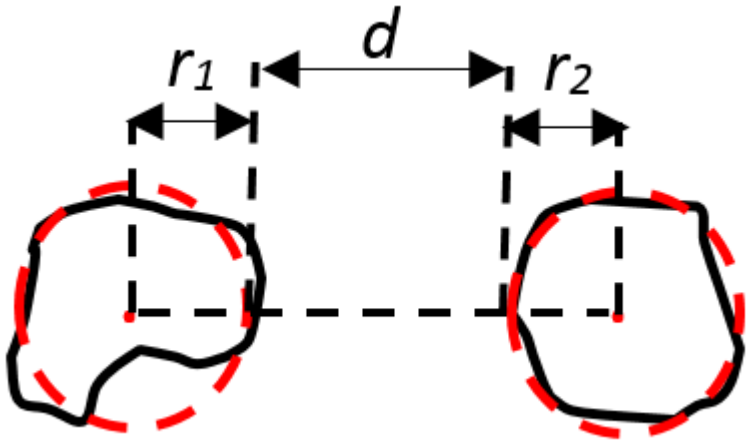
Concrete composition

Volumetric content based on mix design data

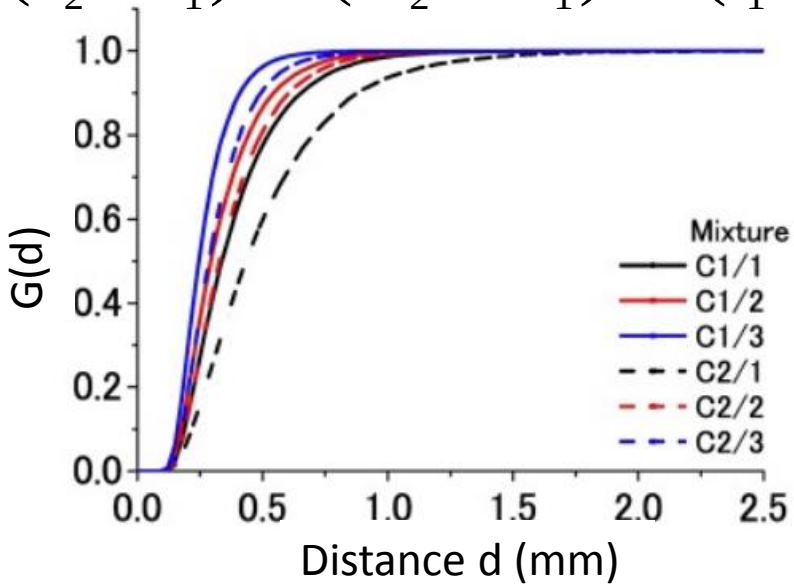
Concrete component	Relative volume content		
	S61	WP	GWB19
Hardened cement paste	0.300	0.260	0.303
Air voids (entrained and entrapped)	0.066	0.016	0.042
Fine aggregate (quartz sand)	0.218	0.208	0.198
Coarse aggregate	0.415	0.516	0.457

Nearest-Neighbour Spacing Distribution





$$d = \sqrt{(Y_2 - Y_1)^2 + (X_2 - X_1)^2} - (r_1 + r_2)$$



L_{av} – the distance between the void boudaries
L_{cav} – the distance between the centers of air voids

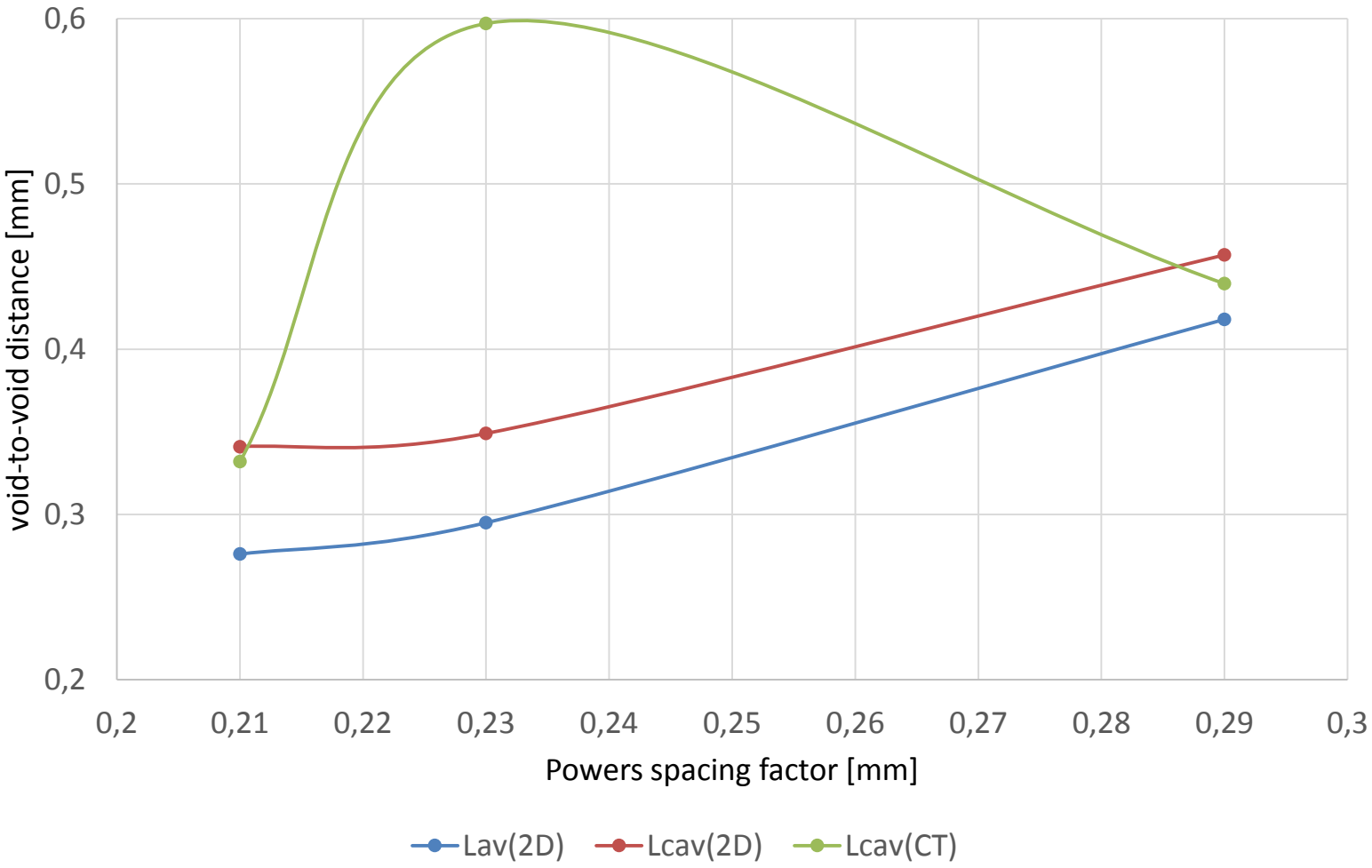
T.Murotani, S.Igarashi, H.Koto, Distribution analysis and modeling of air voids in concrete as spatial point processes, Cement and Concrete Research 115, 124-132, 2019

2D vs 3D

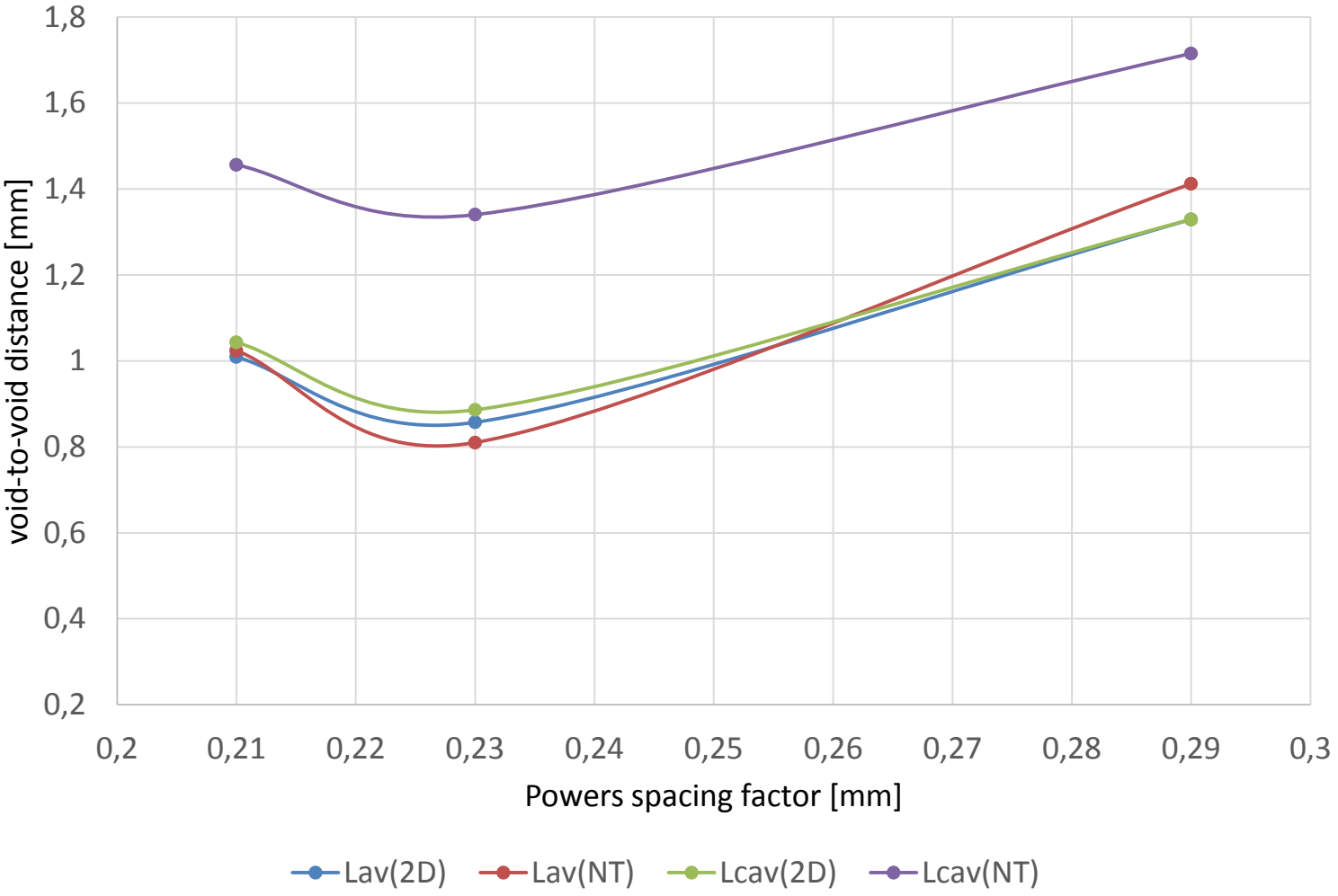
	S61			WP			GWB19		
	standard	2D	CT	standard	2D	CT	standard	2D	CT
A [%]	6.10	7.494	6.227	1.33	1.614	2.144	3.82	6.583	5.125
L_{av} [mm]	0.23	0.295	-	0.29	0.418	-	0.21	0.276	-
L_{Cav} [mm]	-	0.349	0.597	-	0.457	0.4396	-	0.341	0.332
A_{300} [%]	1.42	2.189	0.828	0.53	0.952	0.834	1.94	2.270	1.583

standard – traverse line optical analysis on polished sections (min. 50 μm)
2D – plane optical analysis on polished sections (min. 50 μm)
CT – microtomography analysis (min. 20 μm; *to be repeated for min.50 μm)*

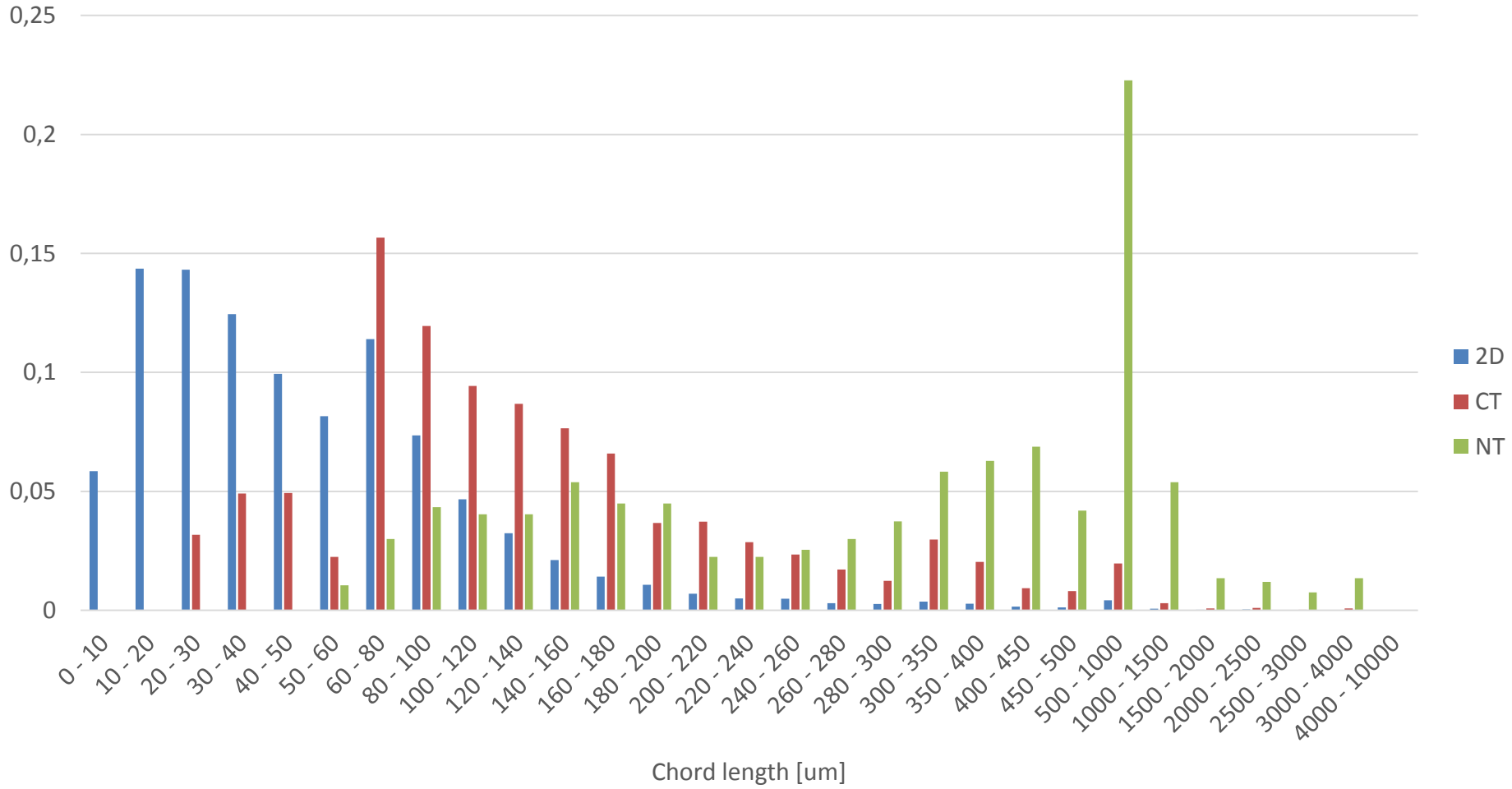
Comparison: 2D&CT vs. standard



Comparison: 2D&NT vs. standard



Chord length distribution in GWB19 concrete (2D - calculations for diameter above 6 µm, CT above 20 µm, NT above 50 µm)



Final remarks

- Void-to-void proximity in concrete determined on using optical plane analysis is confirmed by spatial analysis using μCT, provided that the differences in pixel size are considered
- Characterization of void-to-void proximity by Powers spacing factor is confirmed in industrially produced air entrained concrete
- The distribution of air void chords/diameters is heavily dependent of the pixel resolution
- Supplementary calculations needed, based on X-ray microtomography (treshold value, resolution limit)

ACKNOWLEDGEMENT

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Thank you for your attention!