

Appendix S1 Web of Science Search Strategy.

The bibliometric corpus was retrieved from the Web of Science Core Collection (editions SCI-EXPANDED, SSCI, and CPCI-S) on 29 May 2026. The search paired permafrost/cold-region terms in the Topic field (TS) with infrastructure and engineering terms in the Title field (TI), then applied document-type, language, timespan, and research-category refinements. The exact query was:

TS = ("permafrost" OR "frozen ground" OR "frozen soil")

AND

TI = ("foundation*" OR "pile*" OR "embankment*" OR "subgrade*"

OR "pavement*" OR "runway*" OR "railway*"

OR "thermosyphon*" OR "thermosiphon*"

OR "geotechnical" OR "bearing capacity" OR "thaw settlement"

OR "frost heave" OR "infrastructure")

Refinements applied to the result set:

Timespan: 2001-2026

Document Types: Article, Review Article, Proceedings Paper

Language: English

Web of Science Categories: Geosciences Multidisciplinary; Engineering Civil; Engineering Environmental; Engineering Geological; Construction & Building Technology; Thermodynamics.

Table S1 50 author keywords mapped in Figure 1 and Figure 2, by thematic cluster, with occurrence counts and total link strength.

Cluster	Keyword	Occurrences	Total link strength	Variants consolidated by thesaurus (raw occurrences)
1 (red)	permafrost regions	88	126	permafrost regions (46); permafrost region (42)
1 (red)	qinghai-tibet railway	79	123	qinghai-tibet railway (58); qinghai-tibetan railway (8); qinghai-xizang railway (7); railway embankment (6)
1 (red)	qinghai-tibet highway	30	63	qinghai-tibet highway (17); highway embankment (6); high-grade highway (7)
1 (red)	thermal regime	29	53	thermal regime (23); thermal performance (6)
1 (red)	cooling effect	27	51	cooling effect (27)
1 (red)	thermal stability	25	45	thermal stability (25)
1 (red)	temperature field	23	37	temperature field (23)
1 (red)	two-phase closed thermosyphon	21	44	two-phase closed thermosyphon (21)
1 (red)	cooling performance	21	49	cooling performance (21)
1 (red)	permafrost embankment	19	23	permafrost embankment (14); composite embankment (5)
1 (red)	expressway	19	38	expressway (11); expressway embankment (8)
1 (red)	crushed-rock embankment	18	39	crushed-rock embankment (13); air convection embankment (5)
1 (red)	asphalt pavement	18	23	asphalt pavement (18)
1 (red)	thermosyphon	16	30	thermosyphon (16)
1 (red)	warm permafrost	16	21	warm permafrost (16)
1 (red)	temperature	12	17	temperature (12)
1 (red)	permafrost subgrade	12	11	permafrost subgrade (12)
1 (red)	embankment deformation	11	27	embankment deformation (11)
1 (red)	permafrost thawing	11	20	permafrost thawing (6); thawing (5)
1 (red)	permafrost table	10	17	permafrost table (10)
2 (green)	frost heave	79	94	frost heave (66); frost heaving (8); frost heave deformation (5)
2 (green)	numerical simulation	72	110	numerical simulation (31); numerical analysis (14); numerical modeling (12); finite element model (8); finite element method (7)
2 (green)	frozen soil	53	68	frozen soil (42); frozen soils (6); saturated frozen soil (5)
2 (green)	pile foundation	43	78	pile foundation (19); pile foundations (12); bridge pile foundation (7); cast-in-place pile foundation (5)

2 (green)	settlement	34	60	settlement (21); differential settlement (7); embankment settlement (6)
2 (green)	subgrade	28	33	subgrade (21); railway subgrade (7)
2 (green)	freeze-thaw cycle	26	36	freeze-thaw cycles (11); freeze-thaw (9); freeze-thaw cycle (6)
2 (green)	high-speed railway	21	28	high-speed railway (21)
2 (green)	seasonally frozen soil	18	23	seasonally frozen soil (10); seasonal frozen soil (8)
2 (green)	moisture migration	15	19	moisture migration (10); unfrozen water (5)
2 (green)	frozen ground	14	28	frozen ground (9); seasonal frozen ground (5)
2 (green)	seasonally frozen region	11	14	seasonally frozen regions (6); seasonally frozen region (5)
2 (green)	model test	9	17	model test (9)
2 (green)	deformation	9	21	deformation (9)
3 (blue)	embankment	66	118	embankment (60); embankments (6)
3 (blue)	climate change	63	121	climate change (32); climate warming (26); global warming (5)
3 (blue)	permafrost degradation	49	68	permafrost degradation (49)
3 (blue)	thaw settlement	47	91	thaw settlement (34); thaw consolidation (8); thawing settlement (5)
3 (blue)	crushed-rock layer	25	56	crushed-rock interlayer (8); crushed-rock layer (6); crushed-rock interlayer embankment (6); crushed rock layer (5)
3 (blue)	ground temperature	24	50	ground temperature (24)
3 (blue)	qinghai-tibet plateau	17	25	qinghai-tibet plateau (12); qinghai-tibet engineering corridor (5)
3 (blue)	artificial ground freezing	9	9	artificial ground freezing (9)
4 (yellow)	permafrost	234	348	permafrost (234)
4 (yellow)	cold regions	29	41	cold regions (16); cold region (13)
4 (yellow)	dynamic response	23	33	dynamic response (10); seismic response (8); seismic performance (5)
4 (yellow)	heat transfer	22	38	heat transfer (12); heat accumulation (5); heat flux (5)
4 (yellow)	bearing capacity	16	33	bearing capacity (16)
4 (yellow)	foundation	15	27	foundation (9); tower foundation (6)
4 (yellow)	pile	14	26	pile (9); piles (5)
4 (yellow)	infrastructure	10	18	infrastructure (10)
Total (50 keywords)		1,600	2,588	from 97 raw author-keyword entries