Review

Bibliometric and Knowledge Network of Global Research on Pile Foundations: A Review of Recent Developments

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Review

Bibliometric and Knowledge Network of Global Research on Pile Foundations: A Review of Recent Developments

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Abstract: Foundation on soft soil has always been a challenge for civil engineers, Pile foundation is by far the most suitable and comprehensive idea for construction on soft soil. In the present study, we produce a comprehensive overview of Pile foundation research from 1992 to 2021 by making use of bibliometric analysis. This study is conducted based on the Web of Science Core Collection Database. The Web of Science, MS Excel, and VOS viewer software are used for bibliometric analysis and science mapping. A database of 4803 publications has been retrieved. The analysis results show that People R China has yielded the greatest number of publications. In geographical terms, more than 50% of research is done by Asian countries. People R China and USA have the highest collaboration. Studies in this period are focusing on key factors associated with pile foundations such as Soil structure interaction, Pile group, Settlement, Liquefaction, Bearing Capacity etc. as suggested by the keywords analyzed in these publications. Analysis of the most cited articles in the field of Geotechnical and Geoenvironmental Engineering reveals that the research area has gone vast from analyzing axial behavior and strength of pile foundations to analyzing seismic responses, further moving to sustainable structure and artificial intelligence applications in the concerned field in the last 30 years.

Keywords: Bibliometric analysis; Pile foundation; Sustainable structure; VOS viewer; Web of science

1. Introduction

Pile foundations are that part of the structure which transmits to, and into, the underlying soil or rock the loads supported by the foundation and its self-weight. Pile foundations are the structural members used to transmit surface loads down to lower levels in the soil mass. This may be by vertical distribution of the load along the pile shaft or by direct application of the load to a lower stratum through the pile point. Piles are commonly employed in civil and marine engineering. Many studies on pile foundations have focused on the impact of vertical loads from above structures [1,2]. All piles have a combination of bearing and friction forces through which they transfer the load to the soil. It varies from one kind of soil to another. Rehabilitation and repairing of pile foundations is quite a difficult process. Therefore, strength, serviceability, economy, and constructability are all factors that must be taken into consideration while designing the structure [3]. With certain advantages of pile foundation, this field has evolved apparently in the construction area and some of its allied areas. In early stages of its application, only static and vertical loading was considered. Later on, it has been examined and used for dynamic responses also [4,5]. Geotechnical parameters of soil, such as cohesion, internal friction angle, and many more, exhibit a high degree of variability and uncertainty and cannot be managed using typical deterministic design techniques [6]. Novak was the first to make an attempt to use continuum theory to understand the dynamic response of a single pile [7] further proceeded with other theories [8]. Pile foundations without superstructures have been increasingly popular in seismic research in recent years [9]. Various methods have been developed for soil

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structure interaction examinations, such as the Winkler model [10-12], plane strain model [13,14]. Further group of pile [15-16], combined pile [17, 18], hybrid pile [19], pile subjected to lateral loads [20] owing to earthquakes, wind and water currents, traffic pressures, and soil conditions [21,22] and other advanced pile structures were developed after analyzing by various researchers. Many of the recent studies on pile foundation are done by numerical modelling using various FEM software [23-25].

It is important to evaluate the growth trend in pile foundation research fully and quantitatively, as this can assist academic professionals in making educated decisions about their future studies. Additionally, it is difficult to organize, thoroughly summarize, and quantitatively assess the development trends and characteristics of a particular subject across a vast number of studies conducted over a lengthy period in typical review articles [26]. Pile foundation research, in particular, is an interdisciplinary field that encompasses environmental science [27], marine engineering [28], energy [29], economics, and other fields. Thus, bibliographic analysis is required to provide a full picture of pile foundation research.

In Bibliometric analysis, statistical and mathematical methods are used to quantitatively evaluate various ways of distributing knowledge [30]. A research topic or field's intellectual structure and rising trends are presented by summarizing enormous amounts of data. Bibliometrics aims at a particular research area and scrutinizes the documentation produced, work done by each country, distribution of authors, changes in keywords, and spatiotemporal dynamics, which suggest the trends and reflect the direction of future research [31]. Thus, bibliometrics is widely used to analyses research publications [32], patents [33], international scientific and technological journals [34], institute and country collaborations [35], and other fields [36].

2. Procedure of Analysis

The Web of Science Core Collection Database was used to conduct this investigation. Bibliometric analysis and science mapping are made possible with the use of tools such as MS Excel and VOS viewer. Using bibliometrics, the current analysis is done on research on the Pile foundation from 1992 to 2021 based on various criteria such as number of publications, authors, collaboration, countries, and so on. The study includes the geographical distribution of research areas and extensive analysis of authors, summarizing the trends of research globally in the last three decades. For the purpose of this study, the Science Citation Index (SCI) and the Science Citation Index Expanded (SCI-E) databases of the "Web of Science core collection" are used as object databases, and the search criterion is TS=("PILE FOUNDATION" OR (("PILE*") AND "FOUNDATION*"))). Records are extracted in tab delimited file from the web of science. For each paper in the database, we scrutinized data based on the affiliations and initials of authors, language of publication, names of periodicals, year of publication, names of publishers, geographical locations, keywords, and the number of citations [37]. The citations and the number of publications may be slightly different because the data was collected at a specific time on January 31, 2022. New journals, issues, or articles may have been added to the index over the time period.

Furthermore, the retrieved database was refined to achieve the number of citations and the H-index of authors. The H-index indicates the authors' research quality and academic impact. A high H-index signifies high productivity and impact [38]. If two or more researchers, institutions, and/or countries are involved in a collaborative study, their present research patterns can be examined using cooperative network analysis [39]. Finally, research directions for the future are mentioned.

3. Results

3.1. Type of document

By using the Web of Science database based on research on Pile foundation, we have found that a total of 4803 documents are present in the last three decades, which includes articles, review, abstract etc. To be precise, there are 4494 articles, 102 article proceedings papers, 88 Article Early Access, 70 Review, 29 Editorial Material, 3 Meeting Abstract.

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Table 1. Type of documents with number.

Document Type	N	%
Article	4494	93.5
Article; Proceedings Paper	102	2.1
Article; Early Access	88	1.8
Review	70	1.4
Editorial Material	29	0.6

N- number of documents, %- weightage with respect to total documents

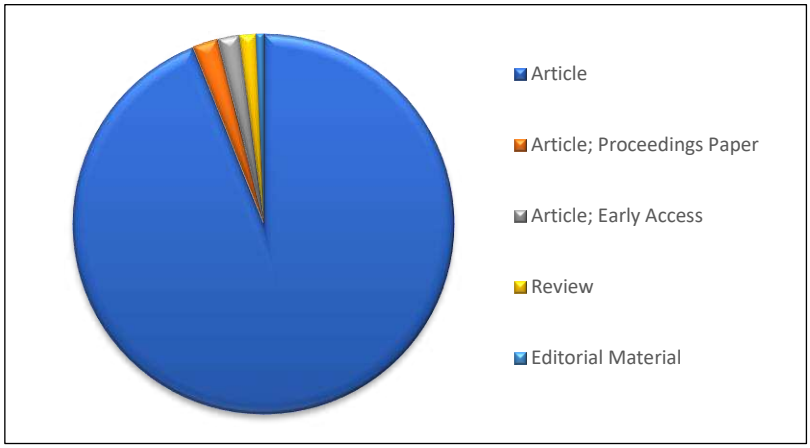

Figure 1. Pie chart representing the weightage of type of documents.

3.2. Features of document computed

With only 18 publications in 1991 to 644 publications in 2021, there has been a remarkable research increment (almost 35 times) in the field of pile foundation. Out of the total 4803 articles, there are 90 such articles that do not have any specified publication year. As shown in fig. 2, there is a marginal increase in the number of publications in the first two decades, i.e., 1992-2010, and then there is a thrust in the research area between 2010 and 2021. The length of a single publication in considered years ranges from 11 to 15 pages. As the research has gone wider in the area, so as the number of publications and, apparently the number of citations. The number of citations is one measure of a publication's scientific quality, since it signifies the publication's effect on the linked study area. In 2014, the total citation is 4991, which is the maximum and could be the reason for the rapid increment in the graph in the last decade. The low number of citations for the year 2021 signifies that the studies are new and will be cited in future studies to come. On the other hand, cited references have surged in every ten years, which shows the credibility, novelty, and usefulness of the publications published in previous years.

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Table 2. Features of document year wise (1992-2021).

Years	P	PG	PG/P	CR	CR/P	TC	TC/P
1992	18	227	13	291	16	418	23
1993	21	267	13	350	17	371	18
1994	33	457	14	539	16	1124	34
1995	26	344	13	582	22	487	19
1996	31	362	12	1025	33	624	20
1997	34	434	13	622	18	1002	29
1998	35	373	11	603	17	916	26
1999	35	494	14	815	23	1184	34
2000	43	484	11	715	17	1529	36
2001	35	462	13	832	24	1674	48
2002	55	696	13	1136	21	1861	34
2003	52	674	13	1140	22	2066	40
2004	60	692	12	1230	21	1803	30
2005	65	932	14	1643	25	1922	30
2006	69	874	13	1431	21	3134	45
2007	61	697	11	1363	22	1728	28
2008	110	1322	12	2638	24	2482	23
2009	108	1380	13	2874	27	3495	32
2010	123	1398	11	3017	25	2846	23
2011	138	1698	12	3356	24	3081	22
2012	166	1964	12	4098	25	3182	19
2013	219	2632	12	5917	27	4362	20
2014	236	3002	13	7125	30	4991	21
2015	268	3334	12	8868	33	4797	18
2016	306	3901	13	9888	32	4388	14
2017	320	4296	13	11616	36	4049	13
2018	377	5023	13	13931	37	3759	10
2019	430	6044	14	16314	38	2771	6
2020	595	8353	14	24301	41	2444	4
2021	644	9393	15	26053	40	636	1

P-number of publications, PG- pages, CR- cited references, TC- citations, PG/P- average number of pages, CR/P- average cited references, TC/P- average citations in a paper.

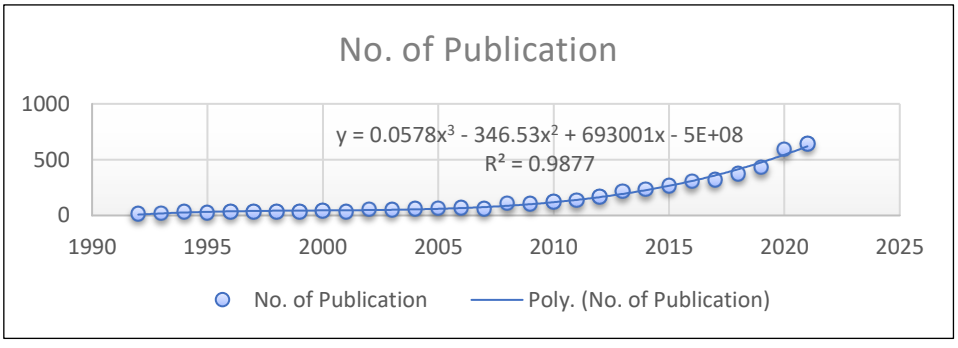

Figure 2. Graph with cumulative publications.

With the above tabled data, we have also performed a regression analysis (Fig-2) where it can be seen that the graph is accelerating in fare manner, having R^2 value equal to 0.9877. Regression coefficients are estimations of unknown publication factors that characterize the relationship between a predictor and a response variable. R^2 coefficient of determination is a statistical measure of how

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well regression predictions approach the observed data points in regression. R^2 value of 1 shows that the regression predictions fit the data exactly.

3.3. Subject Category, Journals and publishers

Data is also categorized and differentiated based on the subject category in which the documents fall. The number of subject categories in which documents are taken is 10, considering significant numbers having percentage higher than 5. Pile foundation research has been done extensively in various filed of science, such as geology, material science, civil engineering, oceanography, and many more. Out of the several fields, 'Geological' engineering field has the maximum number of publications with 2264 publications, followed by 'Geosciences' with 1608, 'Civil' engineering with 1493, 'Construction & Building Technology' with 426 and so on. In Table-3, 'Geological' engineering category has more than half the publications as compared to the core civil engineering category, which is at third position. Presence of 'Computer Science' in the list reveals the diffusion of software in the field of construction as well. Many of the current studies use various numerical modelling software to analyse and design the structures.

Table 3. Top 10 subject category with respective number of publications.

Subject Category	TP	R	%
Geological	2264	1	47.14
Geosciences	1608	2	33.48
Civil	1493	3	31.08
Construction & Building Technology	426	4	8.87
Ocean	402	5	8.37
Materials Science	348	6	7.25
Oceanography	323	7	6.72
Mechanical	303	8	6.31
Computer Science	295	9	6.14
Mechanics	264	10	5.50

TP- Total number of Publications, R- Ranking as per number of publications, %- Percentage of publication.

While analyzing the documents from 1992-2021, out of the top 20 journals, "Soil Dynamics and Earthquake Engineering" is featured with a maximum of 294 publications, while "Journal of Geotechnical and Geoenvironmental Engineering" follows the table with 253 publications. Software evolution in the field of construction and allied areas insists researchers to publish articles in the concerned journals, which can be seen in the table having "Computers and Geotechnics" on the third position with more than 200 publications.

"Proceedings of The Institution of Civil Engineers-Geotechnical Engineering" and "Soils and Foundations" have the same rank as they both have the same number of publications, i.e., 133. "Geotechnique" has highest TC/TP ratio (52.6), on the other hand "Journal of Geotechnical and Geoenvironmental Engineering" being on the second rank has maximum number of Citation which is 7711. Table-4 shows the 20 most productive journals, with ranking corresponding to their number of publications. IF represents the impact factor of the respective journal are taken from JCR. Impact factor is a measurement of the frequency with which the average article in a journal has been referenced in a specific duration, hence higher the impact factor the more the citation of a publication or journal, subsequently reaching a greater extent.

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Table 4. Top twenty Journals that publish Pile foundation related studies.

Journal Name	TP (R)	TC	TC /TP	IF
Soil Dynamics and Earthquake Engineering	294 (1)	5573	19.0	3.718
Journal of Geotechnical and Geoenvironmental Engineering	253 (2)	7711	30.5	4.012
Computers and Geotechnics	205 (3)	4124	20.1	4.956
Canadian Geotechnical Journal	169 (4)	3759	22.2	3.725
Ocean Engineering	135 (5)	1433	10.6	3.795
Proceedings of The Institution of Civil Engineers-Geotechnical Engineering	133(6)	1278	9.6	1.341
Soils and Foundations	133 (6)	2372	17.8	2.436
International Journal of Geomechanics	120 (7)	1396	11.6	3.819
Géotechnique	105 (8)	5518	52.6	4.592
Advances in Civil Engineering	98 (9)	193	2.0	1.924
Marine Georesources & Geotechnology	91 (10)	450	4.9	2.673
Engineering Structures	84 (11)	1180	14.0	4.471
International Journal for Numerical and Analytical Methods in Geomechanics	72 (12)	2279	31.7	4.264
Geomechanics and Engineering	71 (13)	440	6.2	3.223
Soil Mechanics and Foundation Engineering	69 (14)	141	2.0	0.806
Geotechnical Testing Journal	62 (15)	575	9.3	1.469
Acta Geotechnica	60 (16)	774	12.9	5.856
KSCE Journal of Civil Engineering	59 (17)	381	6.5	1.805
Journal of Bridge Engineering	57 (18)	785	13.8	3.066
Bautechnik	52 (19)	135	2.6	0.408

TC-citations, TC/TP- average citations, IF- Impact factor.

Out of total 4803 publications published in a specified duration of three decades, 3666 publications (more than 75%) are published by the top 20 publishers. Publication "Elsevier SCI LTD" is at the top with 763 publications (15.9% of total publications), followed by "ASCE-AMER SOC Civil Engineers" with 591 publications (12.3% of total publications). These two are the only publishers whose percentage of publications is greater than 10% in Pile foundation stream. The rest of the publishers have a lower percentage of publications, ranging from 7 to 1% only. On the contrary, "Elsevier Science BV", being on the 17th position, has the highest ratio (24.31) of citations.

Table 5. Twenty most active publishers in Pile foundation field.

Publisher	TP	(%)	TC	TC/TP
Elsevier Sci Ltd	763	15.9	14360	18.82
ASCE	591	12.3	12757	21.59
Pergamon-Elsevier Science Ltd	335	7.0	7019	20.95
Ice Publishing	265	5.5	4704	17.75
Springer	206	4.3	2131	10.34
Hindawi Ltd	179	3.7	426	2.38
MDPI	165	3.4	638	3.87
Springer Heidelberg	147	3.1	1018	6.93
Japanese Geotechnical Soc	133	2.8	2372	17.83
Techno-Press	113	2.4	723	6.40
Taylor & Francis Ltd	102	2.1	688	6.75
Taylor & Francis Inc	101	2.1	534	5.29
Wiley	96	2.0	1354	14.10
Amer Soc Testing Materials	80	1.7	608	7.60
Elsevier	76	1.6	871	11.46
Canadian Science Publishing, NRC Research Press	72	1.5	1588	22.06
Elsevier Science BV	65	1.4	1580	24.31

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Ernst & Sohn	62	1.3	117	1.89
Korean Society of Civil Engineers-KSCE	58	1.2	372	6.41
Canadian Science Publishing	57	1.2	875	15.35

3.4. Author and Language

While examining the author yield in this particular area of research, it has been seen that the author "El Naggar MH" has topped the list with 59 publications, followed by him "Liu HL'' has total 39 publications. Ratio CP/TP indicates the relation between collaborative and total publication, Table-6 shows 19 out of 20 top authors has published their articles collaboratively. Surprisingly there is only a single author (Liang, FY) who has published an individual publication. Since many of the authors have published the same number of articles, hence it is not easy and righteous to rank them. Sometimes the H-index is the proper criterion to identify authors' yield and valuable contribution in a particular field. Based on this criterion, the author "Randolph, MF" has contributed pre-eminently in the field of pile foundation with an H-index of 68. Apart from him, "Ng, CWW," "Gazetas, G," and "Zhang, LM" are some other authors having an H-index of more than or equal to 50. Fig-3 depicts the total publications of each author in the form of the intensity of color in the picture, dark yellow color indicates the high number of publications. The present picture is obtained with the help of the VOS viewer application.

Table 6. Ten most productive authors of Pile foundation related research.

Author	TP	(%)	IP	CP	CP/TP	H-index
El Naggar, MH	59	1.23	0	59	1	19
Liu, HL	39	0.81	0	39	1	39
Bhattacharya, S	28	0.58	0	28	1	29
Aznarez, JJ	27	0.56	0	27	1	16
Randolph, MF	26	0.54	0	26	1	68
Ling, XZ	26	0.54	0	26	1	19
Ding, XM	26	0.54	0	26	1	20
Maeso, O	25	0.52	0	25	1	17
Wang, KH	24	0.50	0	24	1	16
Huang, MS	24	0.50	0	24	1	30
Jeng, DS	22	0.46	0	22	1	43
Kong, GQ	20	0.42	0	20	1	24
Laloui, L	20	0.42	0	20	1	45
Ng, CWW	19	0.40	0	19	1	50
Ibsen, LB	19	0.40	0	19	1	18
Gazetas, G	19	0.40	0	19	1	50
Liang, FY	18	0.37	1	17	0.95	15
Zhang, LM	18	0.37	0	18	1	51
Zhang, F	18	0.37	0	18	1	26
Sritharan, S	18	0.37	0	18	1	23

TP-Total number of publications, IP- Individual-author publications, CP-Collaboration publications.

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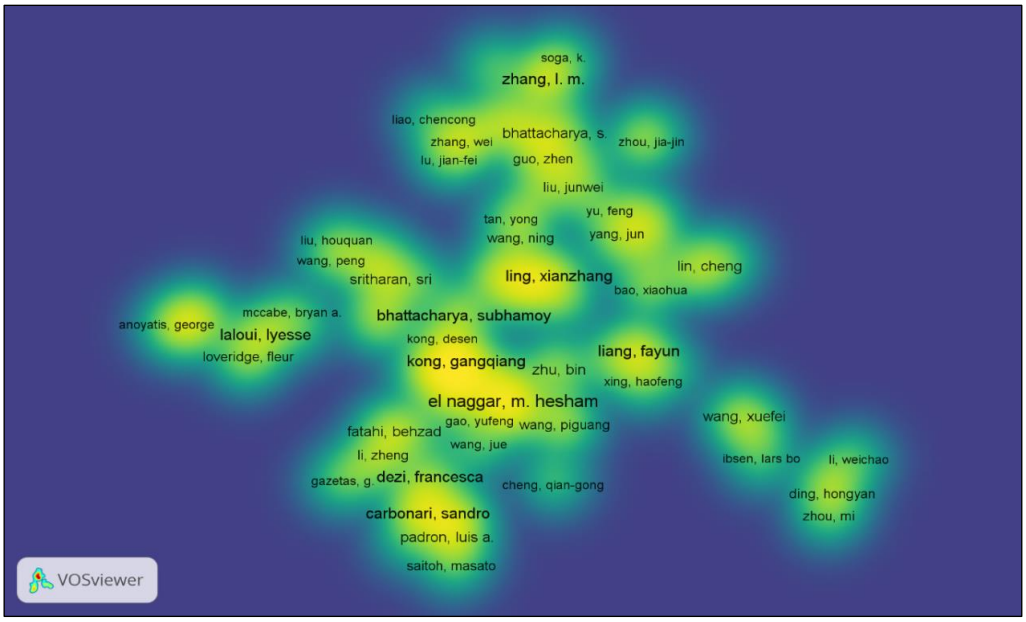

Figure 3. Intensity of authors according to number of publications.

Table 7. Top five languages used in published articles.

Language	N
English	4683
German	87
Spanish	11
Turkish	6
Japanese	4

N- Number of Documents.

Being known that English is the most acceptable language across the globe, maximum number of documents published are in English. Out of 4803 documents, 4683 are in English (approx. 97%), followed by German with 87 documents, 11 Spanish, 6 in Turkish and 4 in Japanese, and a few documents in Portuguese, Croatian, French, Czech, Polish, Finnish, Chinese, and Russian language.

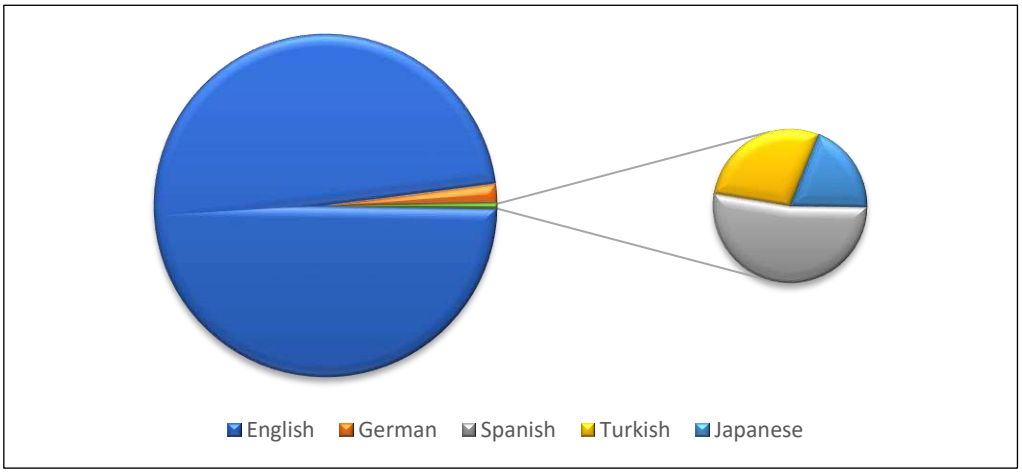

Figure 4. Weightage of Languages in overall publications.

3.5. Author Keyword

Author keywords are extracted and segmented for every decade separately to understand the usage and coverage of each keyword in different times, i.e. 1992-2001, 2002–2011, and 2012-2021. In total, we find 2142 keywords from 1992 to 2021, which is for the last three decades considered in this

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study. 'Pile' being most widely used word is on the top all through three decades as certain as it is, while 'Pile foundation' improved its position in the second decade and keep it for the next decade also positioning itself on second in overall analysis. It can be clearly seen that as research on pile foundation increased in the last decade of consideration, similarly occurrence of keywords also increased exponentially in this period. Word 'Monopile' is practiced interestingly, with 0 in first to 103 in last decade. In Fig. 5 each term is represented by a circle on the map. The figure depicts the co-occurrence of a keyword in extracted publications at a minimum of 5 times. The diameter of the circle shows the number of links between the two keywords. As a result, a wider circle indicates more connections with other keywords. Between two circles, the thickness of the line represents the frequency with which the words are used together.

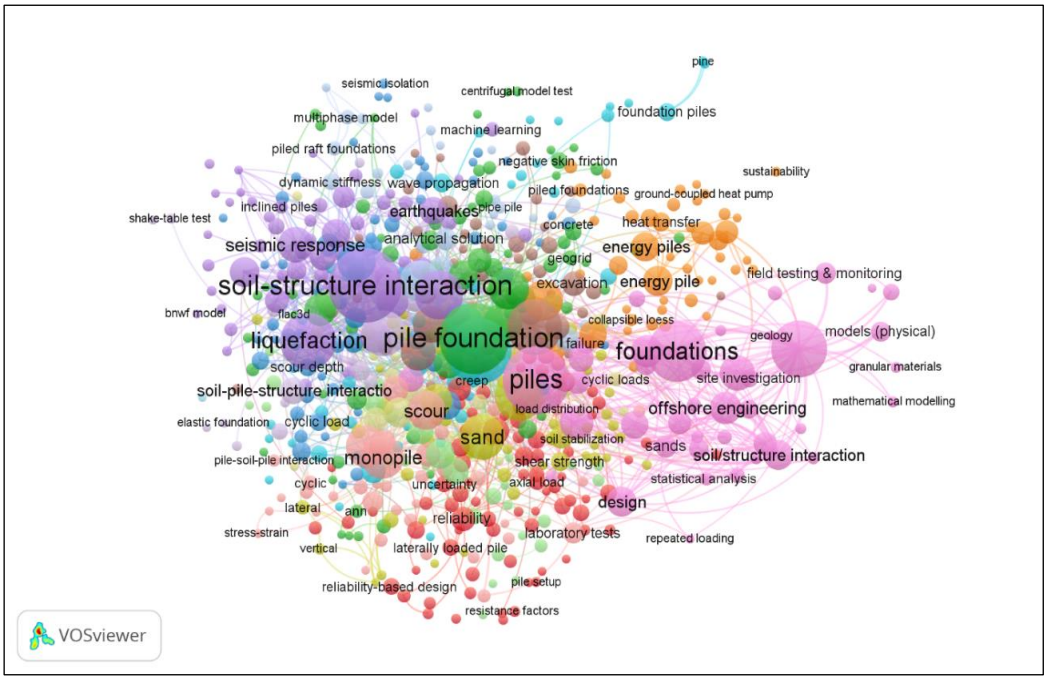

Figure 5. Keyword analysis map.

Table 8. Top ten keywords with temporal differentiation for each decade.

Keywords	1992-2021	1992-2001	2002-2011	2012-2021
Pile	431	48	114	269
Pile foundation	360	16	87	257
Soil-structure interaction	292	19	67	206
Foundation	248	17	76	155
Pile group	159	5	46	108
Settlement	153	16	28	109
Liquefaction	152	5	39	108
Sand	125	6	22	97
Bearing capacity	115	9	17	89
Monopile	107	0	4	103

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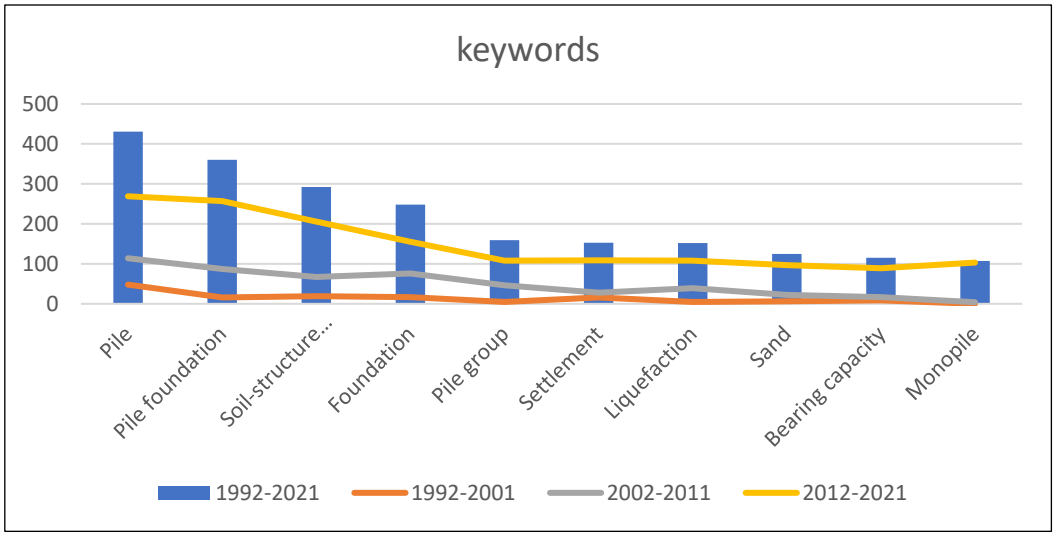

Figure 6. Temporal analysis of Keywords.

3.6. Ten most cited articles in pile foundation research

Table-9 shows the articles that are most cited in the pile foundation field for the selected duration of this study. "Energy foundations and other thermo-active ground structures" [40] article is the most cited with a total citation of 684. The article is published in year 2006 and is still quite useful and relevant for current studies as it is citated for 258 times in the last ten years. "Seismic soil-pile-structure interaction experiments and analyses" [41] is the second oldest article in the list and has the second most citations with 441 times, whereas "Axisymmetrical Time-Domain Transmitting Boundaries" is the oldest article [42] and "Response of stiff piles in sand to long-term cyclic lateral loading" [43] is the newest article with 331 and 275 citations respectively. Analysis of tabled data reflects that energy related work and dynamics in pile foundations are dominant in these years. Total citation data is collected with respect to all database retrieved from the web of science [44-49].

Table 9. Ten most productive articles.

Article	TC	Citation in last 10 years	PY
Energy foundations and other thermo-active ground structures	684	258	2006
Seismic soil-pile-structure interaction experiments and analyses	441	127	1999
Experimental and numerical investigations of the behaviour of a heat exchanger pile	413	109	2006
Science and empiricism in pile foundation design	410	176	2003
Energy pile test at Lambeth College, London: geotechnical and thermodynamic aspects of pile response to heat cycles	385	141	2009
Axisymmetrical Time-Domain Transmitting Boundaries	331	34	1994
Piled raft foundations: design and applications	282	49	2001
Response of stiff piles in sand to long-term cyclic lateral loading	275	138	2010
Behavior of monopile foundations under cyclic lateral load	244	152	2009
A new model and analytical solutions for borehole and pile ground heat exchangers	213	61	2010

TC- Total Citation, PY- Publication Year

3.7. Countries Involved

Peoples of R China is leading all the way as far as the number of publications is considered, with 1672 total publications in the last three decades, followed by the USA with 739 publications, which is

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less than half of the earlier one. Though total citation is highest for the country having the highest number of publications, the ratio of citation to publication is led by Australia (TC/TP=24.30), even if its ranking is fourth out of the top 10 nations worldwide. Data shows that analysis on pile foundation is done in abundance by Asian countries since the top 10 countries consist of 5 Asian countries, 2 countries from the European and American continents. If top two countries are excluded then rest of the countries have less 10 percent of publication individually considering the total publication. Ironically South Korea spends 4.53% of its GDP on research and development, just managing to be in the table of the top ten productive countries in our concerned area. India, being a developing nation is spending only 0.65% of its GDP on R & D [50,51]. Here one matter of fact should be brought in notice, which is that 113 countries' data is missing, or can be said it is not declared in the given data.

While creating a graphical representation on VOS viewer software, the minimum number of documents for considering any country is taken as 3 and the minimum number of citations for a country as 5, where out of 91 countries, 68 meet the thresholds. A VOS viewer created network diagram is shown in fig. 7, which designates different countries and collaboration. The size or intensity of the circle represents the quantity of publications of respective country, and the intensity of the link represents collaboration between the countries.

Table 10. Ten most productive countries/territories conducting Pile foundation related research.

Countries/Regions	TP	TC	TC/TP	%	GDP (in Trillion$)	% of GDP on R&D
Peoples R China	1672	16279	9.74	34.81	13.4	2.14
Usa	739	12305	16.65	15.39	20.49	2.83
England	344	6427	18.68	7.16	2.83	1.70
Australia	303	7363	24.30	6.31	1.33	1.87
Japan	247	4685	18.97	5.14	4.97	3.28
India	237	2965	12.51	4.93	2.72	0.65
Canada	212	3510	16.56	4.41	1.71	1.54
Germany	203	2373	11.69	4.23	4.00	3.13
Iran	191	2678	14.02	3.98	0.61	0.83
South Korea	180	2094	11.63	3.75	1.58	4.53

TP- Total number of publications, TC-Total number of citations, TC/TP- Average number of citations in a publication, GDP- Gross domestic production of country.

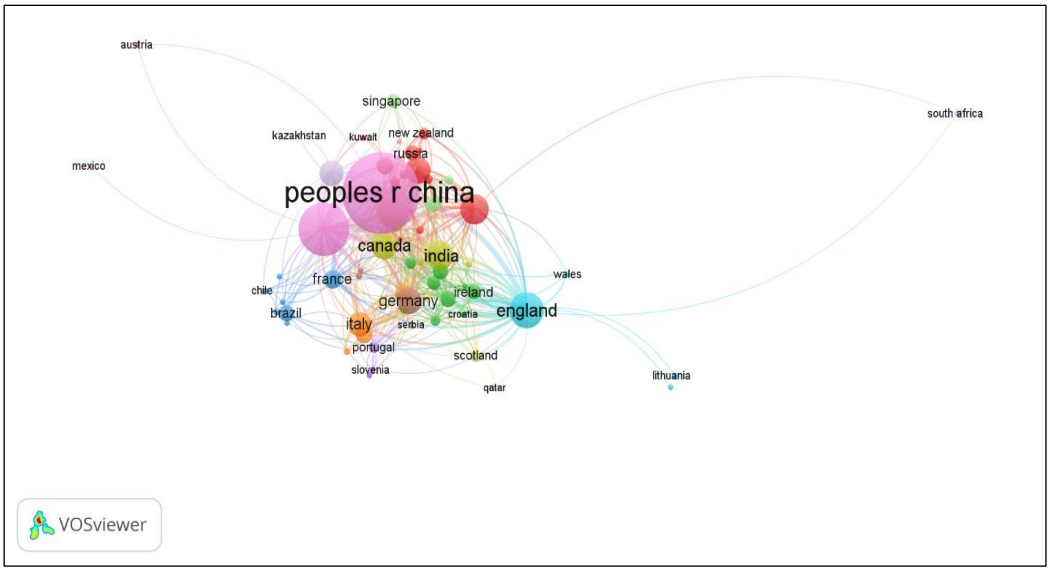

Figure 6. Intensity and collaboration of countries.

4. Conclusions

In the present article, bibliometric analysis has been used to pile foundation literature, allowing for a more accurate classification of prior studies, and facilitating the projection of future work in the field. Using bibliometric analysis, one can look at a wide range of patterns in the existing research, including those between authors, collaboration networks, countries, journals, and keywords. In this article, we present an up-to-date assessment of the research trends in pile foundation based on a bibliometric study of publications published between 1992 and 2021, from a global perspective to a detailed profile.

- According to the statistical findings, there has been a huge increase in pile foundation research over the past three decades, with China accounting for nearly 35% of all publications, reflecting countries in established and emerging economies that are clearly at odds with one another.
- Research on pile foundations has developed rapidly after 2008 and is accelerating exponentially till date, which shows the severity and importance of pile foundations in modern infrastructure taking place round the globe.
- "Geological" is the most common subject category, covering nearly half of the total publications, and English is the most common language.
- Publishers like Elsevier, ASCE are pioneers in cultivating publications, whereas Canadian Science Publishing and Elsevier Science BV are emerging in the field with the quality of publications reflecting a good number of citations.
- As the research on pile foundation has increased in the last decade, it can be seen that every individual area, i.e., soil structure interaction, pile group, settlement, liquefaction, monopile, etc., is touched extensively by researchers.
- Peoples R China which allocates around 2.14 % of its GDP for R&D has nearly 35% of total publications, whereas South Korea allocates highest 4.53% for R&D, out of the top productive countries considered in the study.
- It can be mentioned that future studies will be focused on the dynamics of pile foundations and software involvement with artificial intelligence.

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