Review

A Comprehensive Bibliometric Analysis of Global Research Trends in Performance-Based in Structural Design

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Article

A Comprehensive Bibliometric Analysis of Global Research Trends in Performance-Based in Structural Design

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Abstract: In the context of seismic hazard assessment and engineering design, a comprehensive understanding of local geological and geophysical factor is essential. However, previous studies have lacked crucial components such as local soil condition, ground response analysis, topographic influences, active fault characteristics,slip rates, groundwater behavior, and slope considerations. To ensure the accuracy of seismic hazard map of a country for the safe and cost-effective design of engineering structures in urban areas, a detailed analysis of these factors are imperative. Moreover, multidisciplinary investigations, such as logic tree considerations, are needed to enhance seismic hazard map. Consequently, the adoption of a performance based approach in structural design becomes an urgent necessity. Performance based approach allows engineers to design buildings to specified performance levels (IO, LS, CP) even without a reliable seismic hazard map. This approach is akin to a miracle for countries which doesn't have reliable seismic hazard map. This study presents a systematic and comprehensive bibliometric analysis of academic literature pertaining to performance based design (PBD). By fostering collaborative efforts and expanding research networks, we aim to facilitate the development of coordinated initiatives within the field. Prefered Jouranals ,Leading Countries, Leading Organizations and International institutions identified Utilizing the Scopus database. This study examined 3,469 PBD-related publications spanning from 1969 to 2023 using VOSviewer version 1.6.19, a bibliometric mapping and visualization software tool.Our analysis of co-citations revealed that performance-based design serves as the primary theoretical foundation for structural design and analysis. Furthermore, through a co-word analysis, we tracked the evolution of research topics within the PBD domain over time. This investigation uncovered noteworthy trends, including the steady growth of research output, the increasing prominence of the term "PBD," and a focus on various types of performance based analyses.

Keywords: bibliometric analysis; PBD; co-authorship; author keyword; co-occurrence; scopus database; VOS viewer

1. Introduction

Witnessing the Japan earthquake magnitude 9, Morocco earthquake magnitude 6.8, and Syria and Turkey earthquake magnitude 7.8 left a profound impact [1–4]. The devastation caused by earthquakes, resulting in the loss of a million lives worldwide, every year and that makes it the deadest phenomenon in the planet, which drives our commitment to understanding and mitigating this threat [5].

The adoption of seismic design codes without necessary adjustments can lead to structural failure, especially in tall buildings [6–8]. In countries that do not have earthquake recording stations, where precise seismic hazard maps are unavailable or outdated, reliance on existing hazard maps is common [9–11]. However, these maps do not accurately represent the true seismic risks in those regions. Performance-based design (PBD), an advanced seismic approach, is crucial for designing

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and analysing existing and new tall structures [12–19]. PBD allows engineers to design structures with specific performance goals, even in regions where precise seismic hazard maps are lacking. This adaptability, wherein design parameters can be adjusted based on expected seismic conditions, offers a viable solution for countries facing the challenge of creating reliable seismic hazard maps [20–24]. Implementing PBD alongside necessary design parameter adjustments can enhance building safety and mitigate earthquake risks in such regions [25–29].

As PBD becomes more important, there are several researches that delve into performance-based design in structural design of structures over the last fifty years [30–33]. *Researching prior relevant research can also help academics gain an overview of the scholarly field to make predictions direction of research.* However, due to the subjective character in past studies conducted in the field of PBD, it is necessary to conduct a quantitative literature review that would enable an insight into more areas and disclose the major areas where previous studies concentrated [34–39]. Bibliometrics, a qualitative analysis based on numbers in academic literary sources, provides measurable data [40–43]. The methodology is based on the analysis of data available in databases as bibliometrics. Such statistics provide an understanding of changes that have taken place in literature or scientific knowledge area during a certain period of time [44,45]. Bibliometrics comprises diverse methodologies including citation, co-citation, and bibliographic coupling, as well as a co-word analysis, that use different information for analysis [46–48]. This paper seeks to fill in that research gap through a systematic and quantitative analysis of PBD literature in leading structural journals and earth science and seismic journals with the support of bibliometrics. The study adopts a bibliometric method that incorporates co-citation and co-word analysis to explore and depict the underlying patterns of PBD research in general.

Objective:

This paper aims to analyse recent Performance Based Design (PBD) research trends by examining the dissemination patterns of journal articles. Specifically, our objectives are to:

1. Identify leading authors, countries, and academic institutions contributing to PBD literature.
2. Highlight prevalent terms and research topics within the field.
3. Determine dominant countries based on major PBD applications.

This analysis provides valuable insights for academics, policymakers, and researchers interested in understanding current research trends in PBD and exploring future research opportunities.

2. Literature Review

2.1. Performance Based Design of Reinforced Concrete Structures.

Due to the fact that they are adaptable, long-lasting and cheap, the construction industry has accepted perhaps some reinforced concrete structures [36–38]. They have high weight endurance, which enables security and comfortable living conditions. In this regard, traditional design approaches rely on the minimum code requirements, which may not necessarily be effective for better performance [39]. As a result of these that performance based design has come up, which seems to be more definite and useful in practice [49].

Performance based design considers the desired performance objectives for a structure and tests its behavior under various loading conditions [50–52]. It wants to upgrade the design considering safety, serviceability, sustainability and durability issues. Some of the benefits of this approach include better structural performance, reduced costs of construction, increased resistance to natural disasters and so forth [53–59].

One of the most important parts of performance-based design is performance. This is a description of the behaviour that the material is expected to portray in relation to each loading scenario [60–67]. For instance, acceptable performance can be established to mean that a dwelling remains operational if a moderate earthquake building fails during an intense earthquake. That enables designers to target performance levels that maximise materials utilization [68–74].

Another aspect of performance based design is the advanced analysis techniques [75,76]. However, unlike traditional design methods, simplifications and assumptions rarely accurately

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represent the structure behaviour. However, performance-based design utilizes high-tech computer software and numerological models that simulate the structure's performance in different dependencies [77–83]. This allows the designers to analyse and improve the structure performance by changing its design [84–86].

Secondly, the choice of materials and construction methods is vital for performance-driven design [87–89]. The use of high-performance materials such as high-strength concrete and steel reinforcement improves structural performance and reduces material requirements [90–92]. Furthermore, utilization of contemporary manner of fabrication, for instance, precast concrete systems and post-tensioning systems, can further reinstate the efficiency and lifespan of reinforced concrete infrastructure [93–96].

Sustainability principles are another factor by which performance-based design can be characterised. The whole purpose of looking at a structure's environmental quality over its life cycle is to help the designers optimize resource use and minimize waste. For example, sustainable materials, low-energy design, and recycling and waste management [97].

That is why performance-based design of reinforced concrete structures is a widespread and dependable approach. Performance optimization, structure performance, durability, and resilience ensure the safety, security, and health of the occupants, enhance overall environmental sustainability, and efficiently use built space [98].

2.2. Bibliometric Analysis

2.2.1. Bibliometric Analysis: Unlocking Insights from Scientific Literature

With the information overflow, every day, myriad scientific articles are posted in various fields, making it very difficult to track down what is up-to-date and important [99]. It is here that bibliometric analysis comes in handy by offering a systematic and quantitative avenue for the evaluation and analysis of scientific literature [40].

Bibliometric analysis refers to a form of quantitative analysis conducted using statistical methods on individual or combined bibliographic databases to study impacts, patterns and trends in specific areas of research [47]. Only the bibliometric analysis of scholarly publications encompassed a variety of characteristics regarding citation patterns, authorship, and journal impact that reveal important features in this world [41].

Bibliographic analysis citation count may determine the role or significance of an article to the science community by researchers [100]. The development of citation analysis in locating landmark literature, key opinion leaders, and developing areas. The tool also assists researchers to compare their output and find possible partners and directions to be researched [42].

For instance, co-authorship analysis is very important in bibliometric analysis. Researchers could identify networks and communities of authors working in the same area in several ways [43]. This exposure may help identify potential research collaborations and partnerships. It also helps determine popular authors within their specific fields as co-authors for the materials [101].

One other useful application of bibliometric analysis is journal impact analysis. Researchers use the concept of the impact factor to measure a journal's repute and influence in a particular field [44]. The analysis of journal impacts assists researchers in selecting high-ranking, influential publications for their research, thus ensuring wide publication and effective recognition [45].

Further, the analysis makes it possible to discover new research lines or 'hot topics' in a particular field [102]. By analyzing the frequency of keyword/concept use in scholarly publications, emerging interest and need for research can be identified [103]. Such information is helpful for researchers who wish to open new paths in future research or contribute to newly formed fields [104].

Bibliographic analysis, however, has wider applications, including measuring the performance of individuals or organizations or nations, even research groups [105]. Research productivity and impact of various entities can be assessed by evaluating the publication output, citation impact, and collaboration patterns. It provides grounds for comparing and evaluating the expenditure of funds and figuring out strategy [106].

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However, these bibliometric limits need to be noted. It is often determined by what bibliographic data can be found and how dependable it is in different databases [107]. Additionally, it ignores the kind or worth of research apart from citations and may not include all interdisciplinary activities or non-traditional forms of publications [108].

Nevertheless, bibliometric analysis does have some flaws; yet it may be still used as a significant means for researchers, policy makers and funding agencies to study the scientific landscape [109]. It is a quantitative and evidence based approach to assess research impact, identify important works, and discover emerging trends [46]. Bibliometric analysis can enable researchers to be informed and take correct decisions, cooperate with each other and raise knowledge production in their own field [47].

3. Materials and Methods

Bibliometrics is a statistical analysis tool of publication that offers quantitative insight into academic literature. As mentioned by analysing data collected in the database, such as quotes, writers, keywords, or the number of articles read, the bibliometric analysis provides insight into the growth of literature and information transfer over a while within a given field. Bibliometrics includes various approaches such as citation analysis, co-citation analysis and bibliographic linking quotation, and co-word analysis for keywords, depending on which data it uses in research.

Data mining was carried out using the Scopus database from 1983 to 2023. The main theme of this thesis was a review article in the title and abstract that included " **performance based design*.**"The oldest and most recent dates of publication return to 1983; the latest one is 2023. The search question string used was:

TITLE-**ABS-KEY (“performance based design*.”) AND (LIMIT-TO (LANGUAGE, "English”)).** This query string's output was 3456 documents.

The Single country publication (S.C.P) information was obtained by restricting the search results to a specific country using the field code AFFILCOUNTRY. Source, author, affiliation, country/territory, subject area and type of document are dependent on year, the central theme search results were analyzed. Bibliometric metrics have been used for ranking purposes, for instance, total articles, total citations, and h-index

3.1. The Bibliometric Maps

Citation, bibliography, and author keywords of 3456 publications have been exported to VOSviewer (version 1.6.19, Center for Science and Technology Studies, Leiden University, The Netherlands), a bibliometric mapping and visualization software tool. Maps contain items generated with VOSviewer. The items are the interest objects in this analysis and the keywords or countries of the author. There may be a link between any pair of items, connection or relationship between two items. Every relation has a strength which represents a positive value for numbers. The higher the value, the higher the relationship. The country-to-country link strength shows the number of publications co-authored for co-authorship study by two linked countries, whereas the cumulative strength of the connection indicates the total strength of a country's co-authorship connections with other countries. Likewise, the strength of the author's keyword association reflects the number of publications in which the co-occurrence study includes two keywords. In addition to that citation, bibliographic coupling and co-citation analysis types with full counting method were incorporated in this paper. we have ignored documents with a large number of authors, a maximum of 25.

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4. Results

4.1. PART–1: Co-Authorship Analyzes:

Under this category we used the unit of analysis authors, organizations, and countries.

4.1.1. Category -I Co-Authorship -Author's case -1

Our result showed that under this category, out of 3114 authors, only 7 meet the thresholds for each author. We calculated the total strength of the co-authorship links with other authors. The authors with the greatest total link strength were selected, as shown in Table 1.

Table 1. Verified selected authors.

Id	Author	Documents	Citation
474	Chow w.k.	6	118
489	Chuang w.-c.; Spence s.m.j.	5	83
1000	Hamburger r.o.	5	6
2547	Suksuwan a.; Spence s.m.j.	6	45
2665	Tort c.; hajjar j.f.	6	18
2771	Wang a.j.	5	17
2811	Wang y.; rosowsky d.v.	5	27

4.1.2. Category -I Co-Authorship -Organization's Case 2

Our result showed that under this category out of 5620 organizations 26 meet the thresholds.

For each of the 26 organizations the total strength of the co-authorship links with other organizations were calculated. The organizations with the greatest total link strength were selected as shown in Table 6. ***Urmia University Department of civil engineering*** in Iran is the leading university in this category.

4.1.3. Category -I Co-Authorship -Countries' Case 3

Our result showed that under this category, out of 140 countries, 53 meet the thresholds.

For each of the 53 countries, the total strength of the co-authorship links with other countries was calculated. The countries with the greatest total link strength were selected as shown in Table 7. As per our analysis result***, the United States is the leading country in this category,*** as shown in Figure 1.

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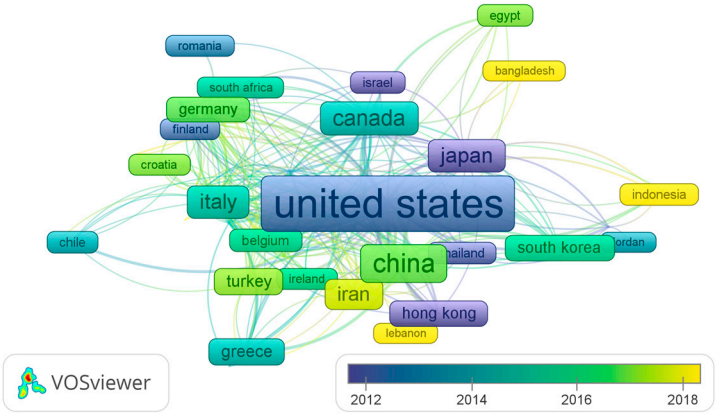

Figure 1. The total strength of the co-authorship links with other countries.

4.2. PART – 2: Co-Occurrence Analysis

Under this category, we used the unit of analysis of **all keywords**, **author keywords**, and **index keywords**.

4.2.1. Category -II Co-Occurrence -All Keywords Case -1

Our result showed that under this category out of 17176 keywords, 1801 meet the thresholds.

For each of the 1801 keywords, the total strength of the co-occurrence links with other keywords was calculated. The keywords with the greatest total link strength were selected. Similarly, the keyword 'performance-based design' is the most frequently used keyword in most scholarly documents, as shown in Figures 2–4.

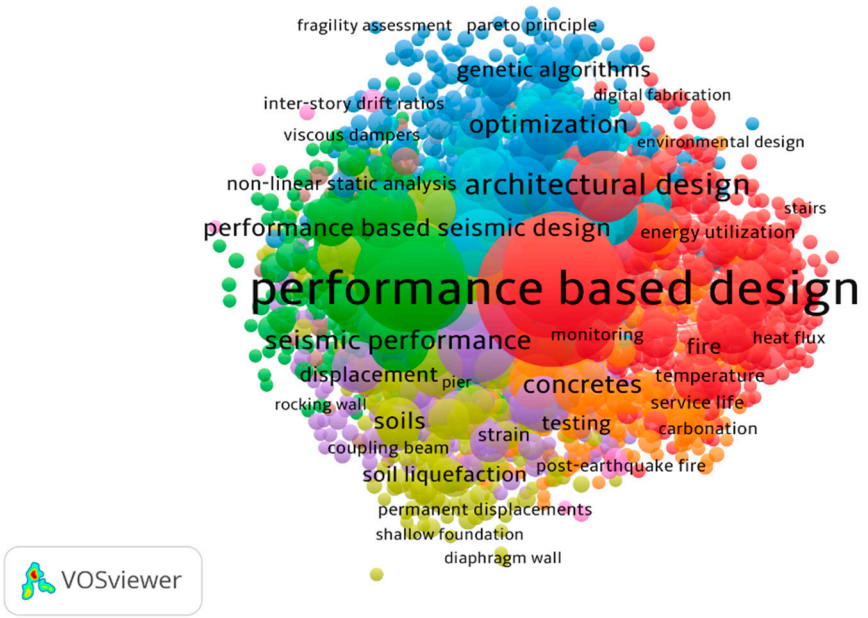

Figure 2. Visualized Co-occurrence -All keywords Analysis Overall Result.

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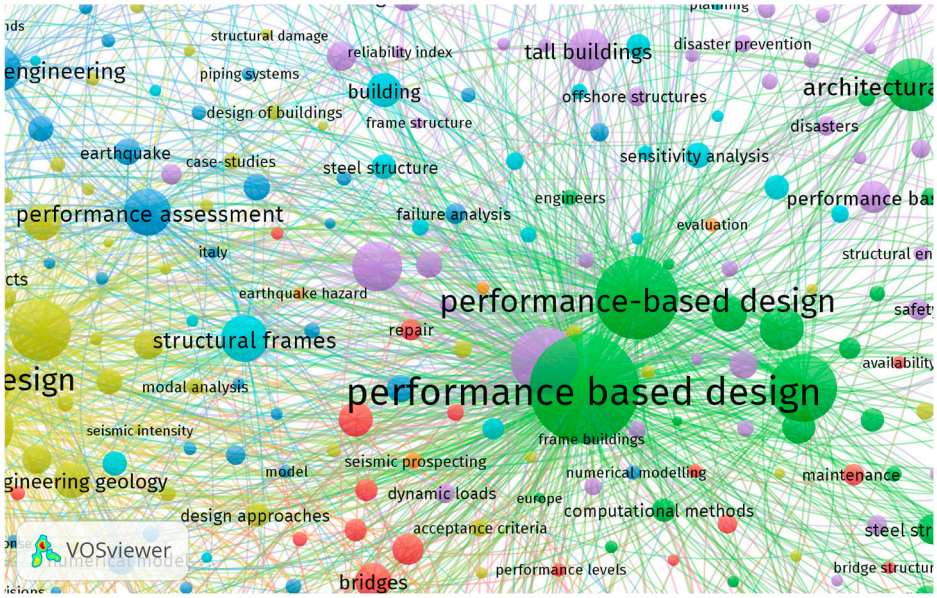
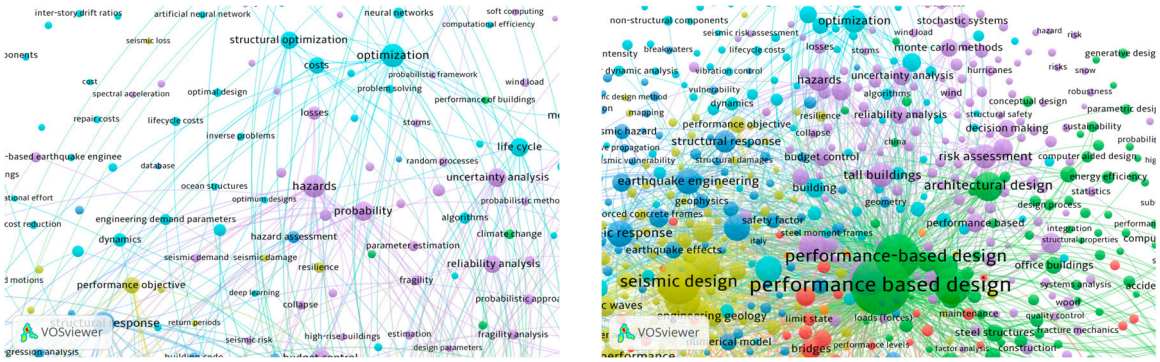
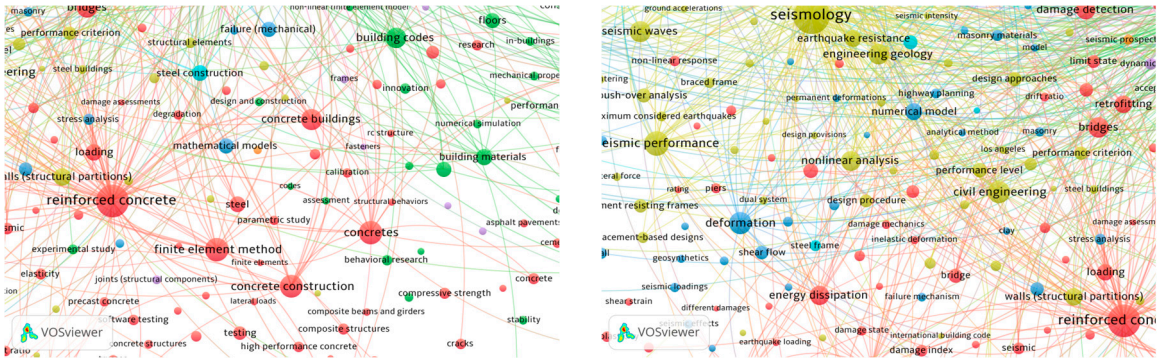


Figure 3. Visualized Co-occurrence -All keywords Analysis Result.



(a) (b)



(c) (d)

Figure 4. Close-up view to Category -II Co-occurrence -All keywords case -1 (A) Top-left quadrant. (B) Top-right quadrant. (C) Bottom-left quadrant. (D) Bottom-right quadrant.

4.2.2. Category -II Co-Occurrence -Author Keywords Case -2

Our result showed that under this category out of 6956 keywords 381 meet the thresholds.

For each of the 381 keywords, the total strength of the co-occurrence links with other keywords was calculated. The keywords with the greatest total link strength were selected as shown in Figures 5 and 6. As per the analysis result, the keyword 'performance-based design' is the most frequently co-occurrence word in most scholarly journals.

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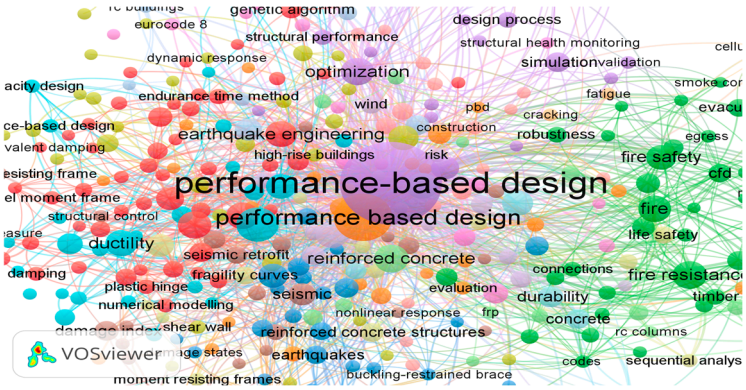

Figure 5. Close-up view and Visualization of Co-occurrence -Author keywords.

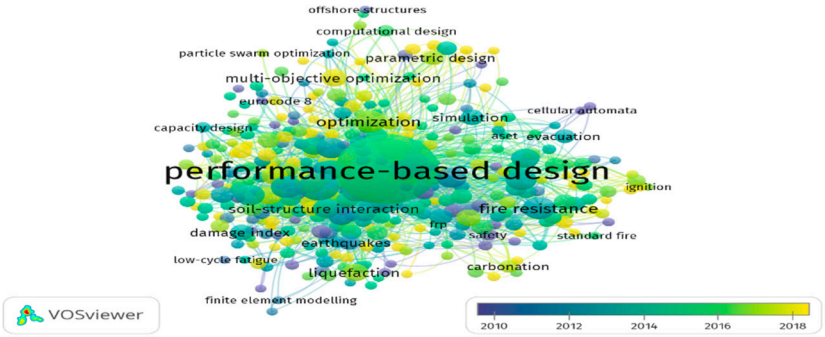

Figure 6. Visualisation of Co-occurrence -Author keywords Overall Result.

4.2.3. Category -II Co-Occurrence -Index Keywords Case -3

Our result showed that under this category out of 13502 keywords 1587 meet the thresholds.

For each of the 1587 keywords, the total strength of the co-occurrence links with other keywords was calculated. The keywords with the greatest total link strength were selected. As per the analysis results shown in Figures 7 and 8, the word 'performance-based **design**' is the most used word in the scholarly community.

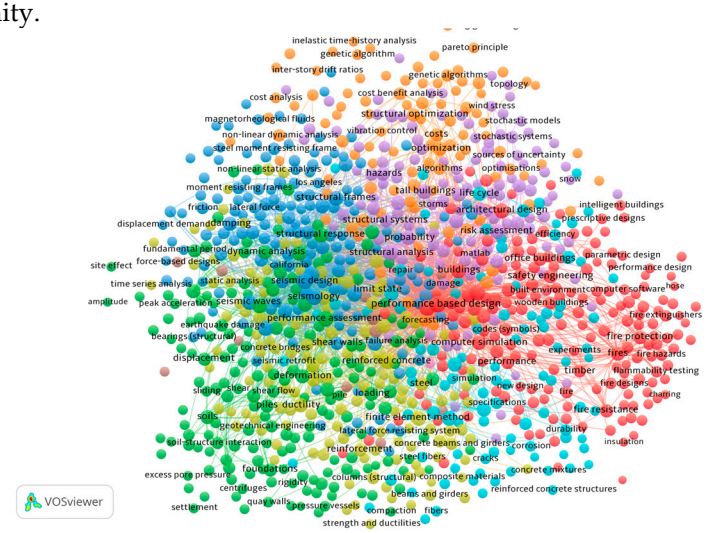

Figure 7. Visualisation of Co-occurrence -Index keyword Bibliometric map.

The 1000 most frequent keywords are displayed in the map. The text of the items is only shown for the keywords with 200 occurrences or more. The co-occurrence connectivity line is only rendered if the value is higher than 10.

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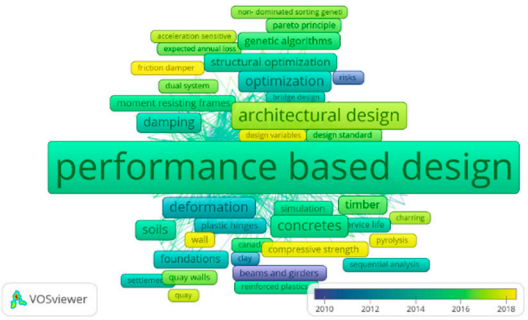

Figure 8. Visualisation of Co-occurrence -Index Bibliometric map of keyword. The text of the items is only shown for the keywords with 200 occurrences or more. The co-occurrence connectivity line is only rendered if the value is higher than 10 for the year 2010 -2018.

4.3. PART – 3: Citation Analysis:

Under this category, we used the unit of analysis **documents, sources, authors**, **organizations** and **countries.**

4.3.1. Category -III Citation – Document's Case -1

Our result showed that under this category out of 3469 documents, 3469 meet the thresholds.

For each of the 3469 documents, the number of citation links was calculated. The documents with the largest links were selected, as shown in Figure 9.

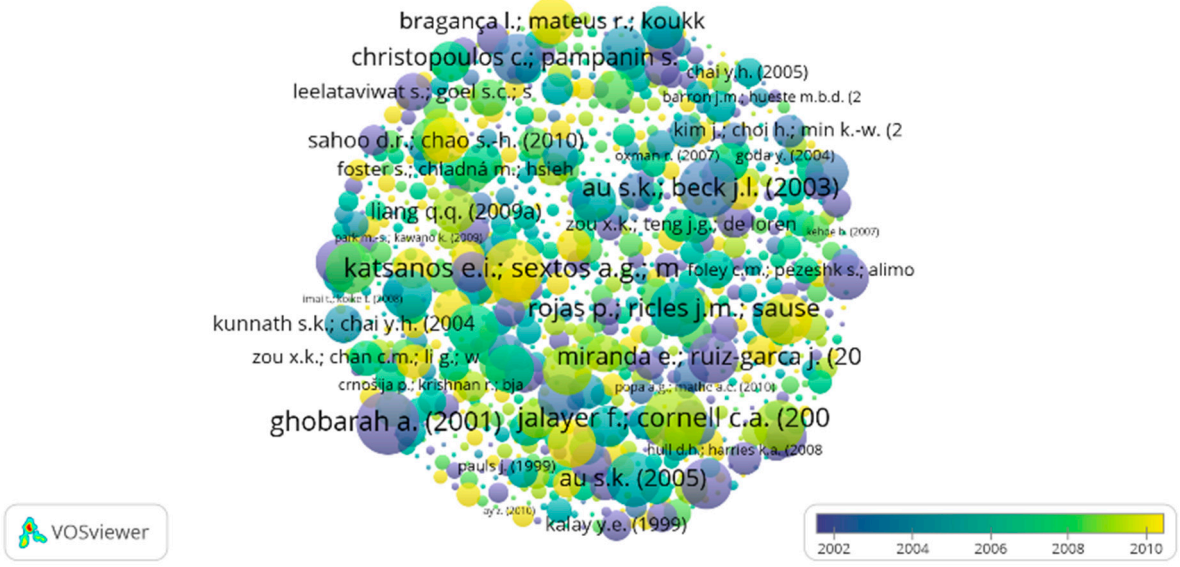

Figure 9. Visualization of Citation – Document Analysis for the year 2002 – 2010.

4.3.2. Category -III Citation – Source's Case -2

Our result showed that under this category out of 972 sources 159 meet the thresholds.

For each of the 159 sources the total strength of the citation links with other sources were calculated. The sources with the greatest total link strength were selected. The result showed that most cited papers are from the **engineering structures** and **earthquake engineering structures journal** as shown in Figure 10.

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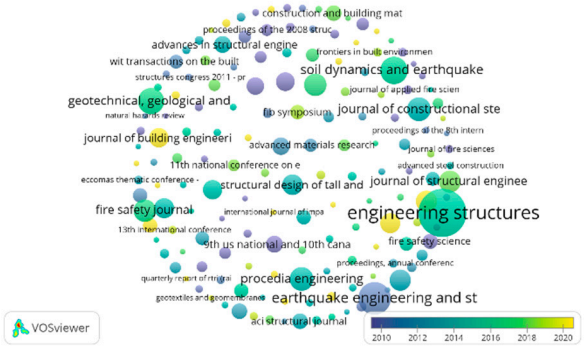

Figure 10. Visualization of Citation – Source's analysis for the year 2010 to 2020.

4.3.3. Category -III Citation – Author's Case -3

Our result showed that under this category, out of 3114 authors, 7 meet the thresholds.

For each of the 7 authors, the total strength of the citation links with other authors was calculated. The authors with the greatest total link strength were selected, as shown in Figure 11.

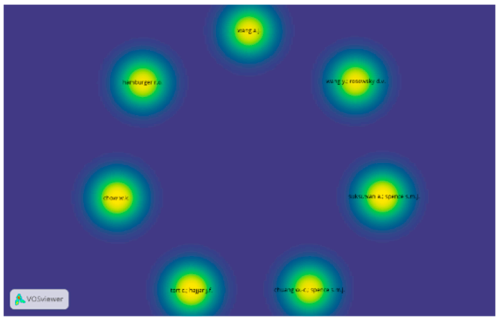

Figure 11. Visualization of Citation – Author's Analysis.

4.3.4. Category -III Citation – Countries Case -4

Our result showed that under this category, out of 140 countries, 53 meet the thresholds.

For each of the 53 countries the total strength of the citation links with other countries were calculated. The countries with the greatest total link strength were selected and **US** was the leading country in this category as shown in Figure 12.

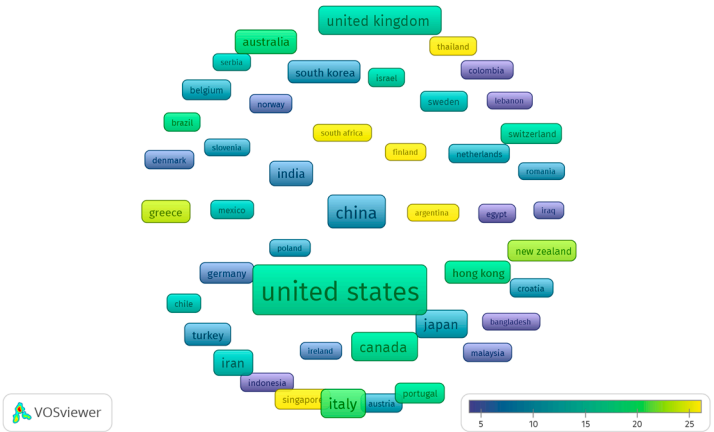

Figure 12. Visualization of Citation – Countries for the year 2012 to 2018.

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4.4. PART – 4: Bibliographic Coupling Analysis:

Under this category we used the unit of analysis **documents, sources, authors, organizations and countries.**

4.4.1. Category -IV Bibliographic Coupling – Document's Case -1

Our result showed that under this category out of 3469 documents 3469 meet the thresholds. For each of the 3469 documents the total strength of the bibliographic coupling links with other documents were calculated. The documents with the greatest total link strength were selected as shown in Figures 13 and 14.

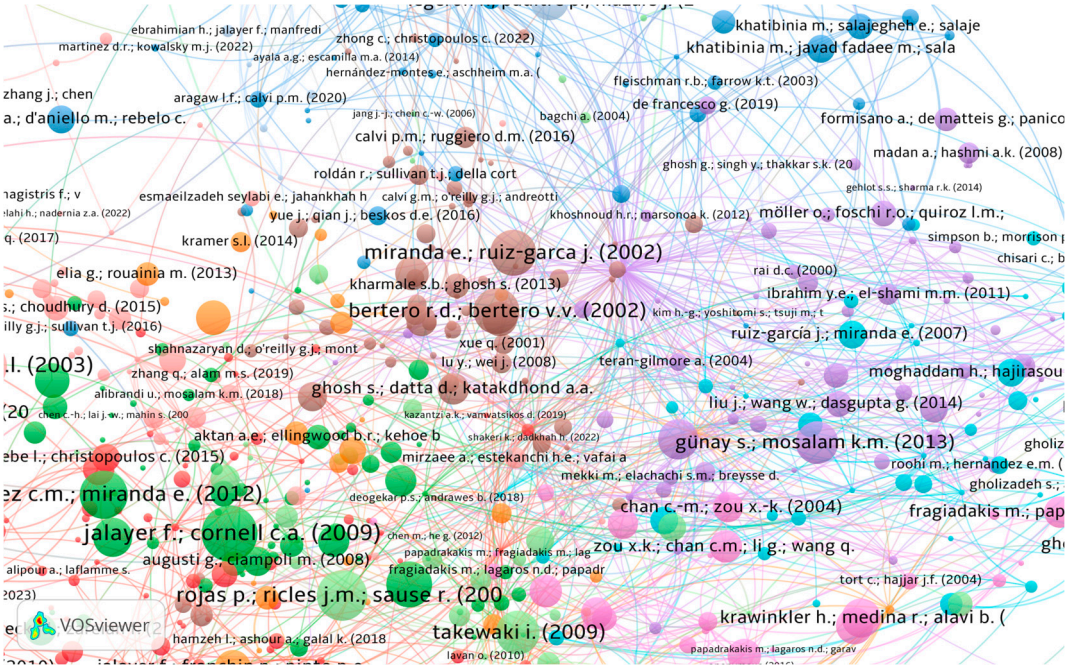
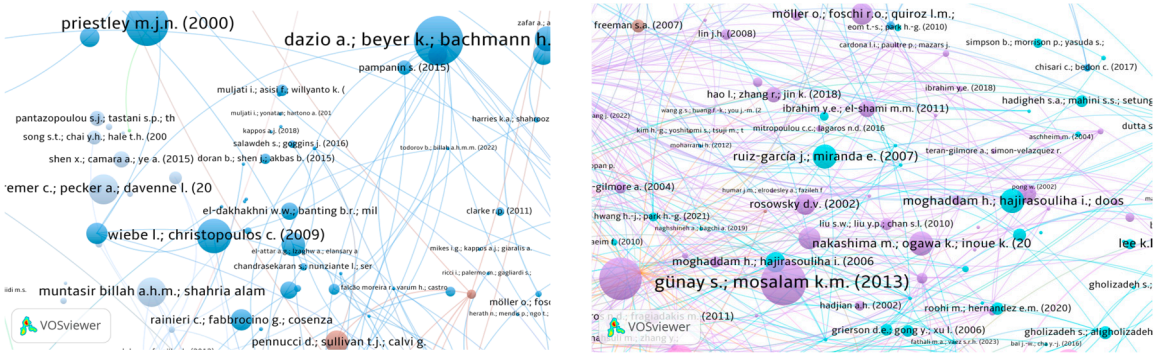


Figure 13. Close-up view to the Category -IV Bibliographic coupling – Document's case -1 .



(a) (b)

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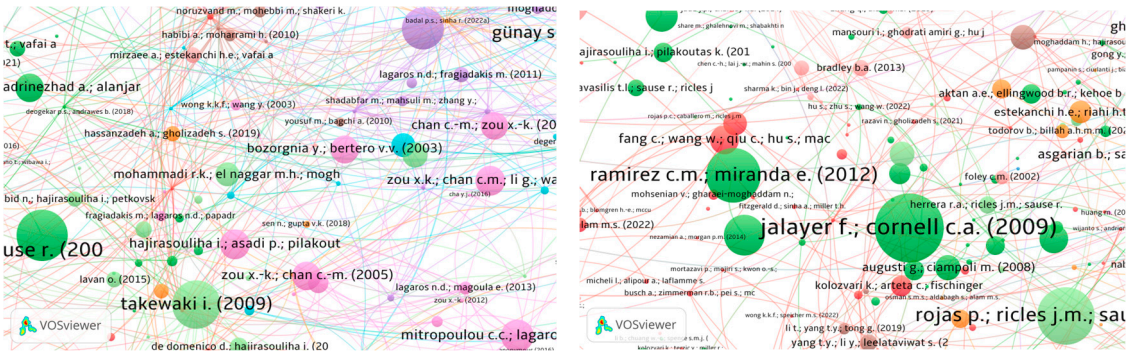


(c) (d)

Figure 14. Close-up view to the Category -IV Bibliographic coupling – Document's case -1. (a) Top-left quadrant. (b) Top-right quadrant. (c) Bottom-left quadrant. (d) Bottom-right quadrant.

4.4.2. Category -IV Bibliographic Coupling – Sources Case -2

Our result showed that under this category out of 972 sources 159 meet the thresholds.

For each of the 159 sources, the total strength of the bibliographic coupling links with other sources were calculated. The source with the greatest total link strength was ***engineering structures*** selected, as shown in Figures 15 and 16.

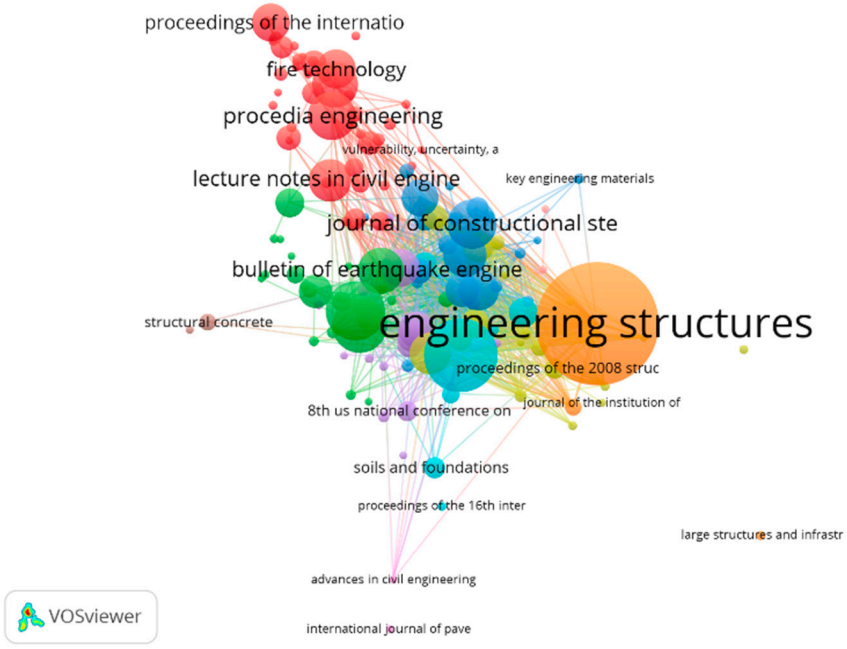
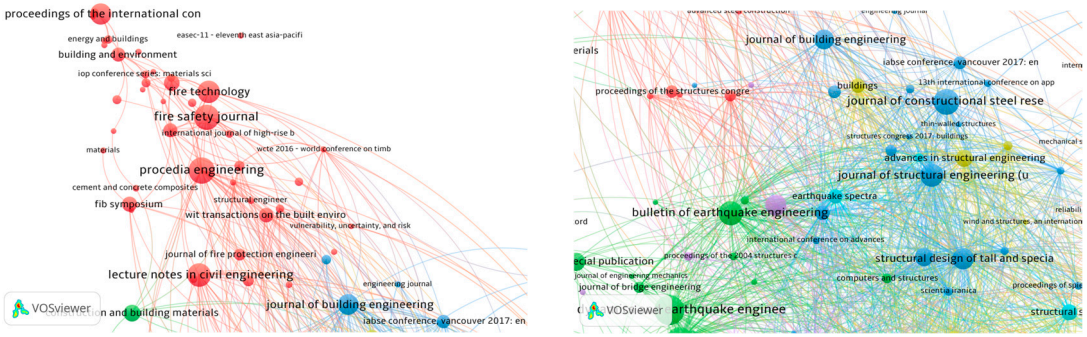


Figure 15. Bibliographic coupling – sources Analysis.



(a) (b)

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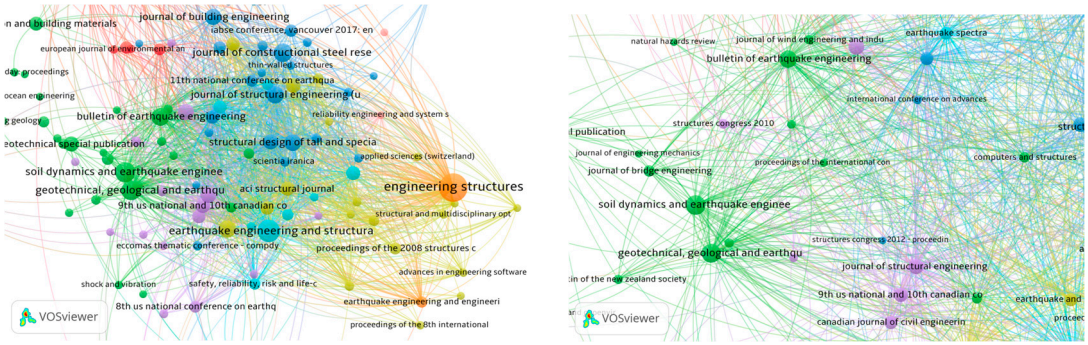

(c) (d)

Figure 16. Close-up view to the Category -IV Bibliographic coupling – Document's case -1. (a) Top-left quadrant. (b) Top-right quadrant. (c) Bottom-left quadrant. (d) Bottom-right quadrant.

4.4.3. Category -IV Bibliographic Coupling – Author's Case -3

Our result showed that under this category out of 3114 authors 7 meet the thresholds.

For each of the 7 authors the total strength of the bibliographic coupling links with other authors were calculated. The authors with the greatest total link were selected. This result shows that in different analysis the result of the authors which meet the thresholds is only 7. In addition to that in the co-authorship analysis the result remains the same this analysis result reviles that in the field of performance based design there are no strong co-authorship link between scholars in different countries and universities this was one of the critical findings of his analysis.

4.4.4. Category -IV Bibliographic Coupling – Organization's Case -4

Our result showed that under this category out of 5620 organizations 26 meet the thresholds.

For each of the 26 organizations the total strength of the bibliographic coupling links with other organizations were calculated. The organizations with the greatest total link strength were selected ; ***Department of civil engineering Urmia university form Iran*** takes a lead in this category with 17 documents and 400 citations as shown in Figure 17.

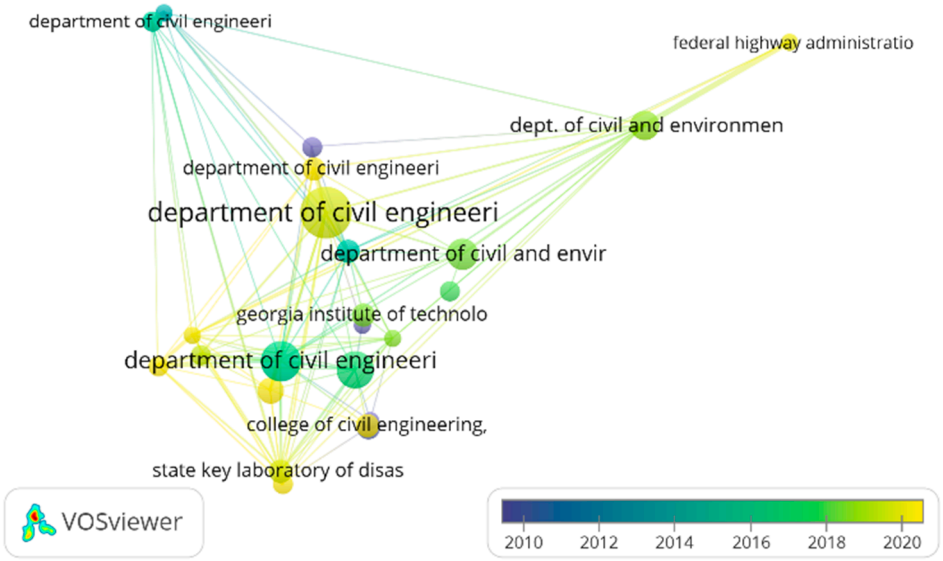

Figure 17. Bibliographic coupling – Organization's analysis result for the year 2010 -2020.

4.4.5. Category -IV Bibliographic Coupling – Countries Case -5

Our result showed that under this category out of 140 countries 53 meet the thresholds.

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For each of the 53 countries the total strength of the bibliographic coupling links with other countries were calculated. The countries with the greatest total link strength were selected. ***United States*** takes a lead as shown in Figure 18 bibliographic coupling analysis result.

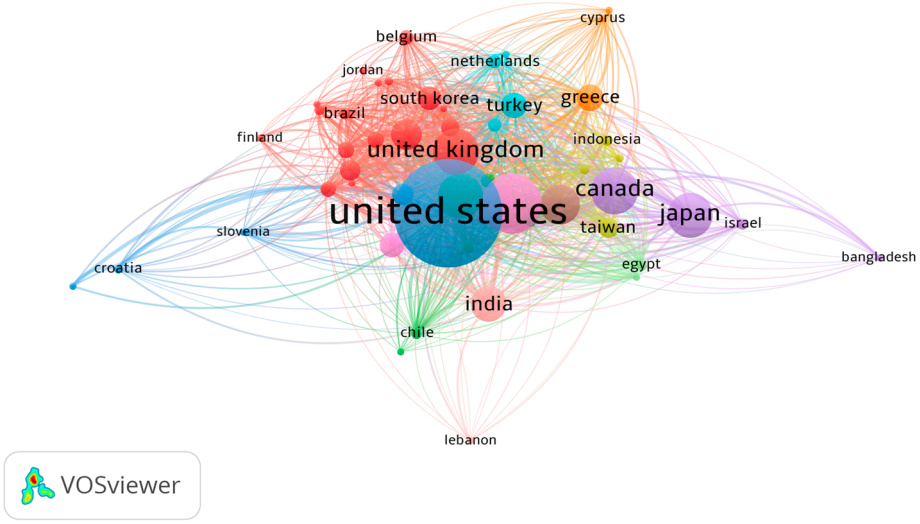

Figure 18. Visualization of Bibliographic coupling – countries.

4.5. PART – 5: Co-Citation Analysis:

Under this category we used the unit of analysis **cited references**, **cited sources**, and **cited authors**.

4.5.1. Category -V Co-Citation –Cited References Case -1

Our result showed that under this category out of 84956 cited references 24 meet the thresholds.

For each of the 24 cited references the total strength of the co-citation links with other cited references were calculated. The cited references with the greatest total link strength were selected and **prestandard and commentary for the seismic rehabilitation of building 2000** paper leads this category by 135 citations and 150 total link strengths as shown in Figure 19.

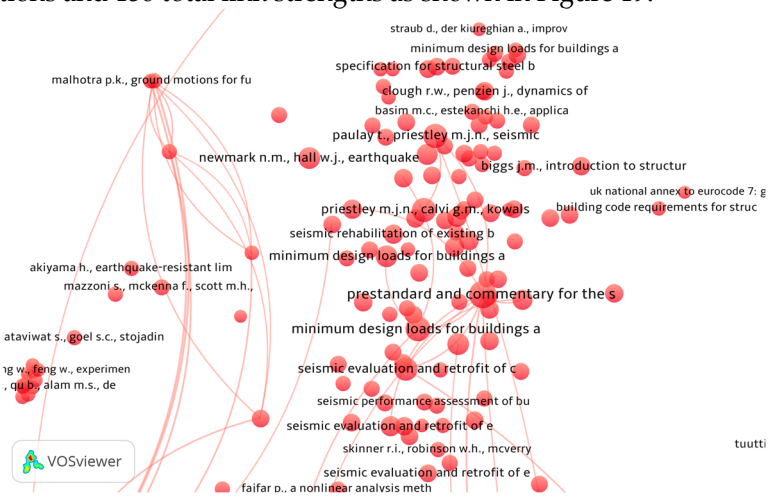

Figure 19. Visualization of Co-citation –cited references.

4.5.2. Category -V Co-Citation –Cited Sources Case -2

Our result showed that under this category out of 80 sources all 80 meet the thresholds. For each of the 80 sources the total strength of the co-citation links with other sources were calculated. The

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sources with the greatest total link strength were calculated; ***International offshore and polar engineering conference*** took the lead in this category with only 4 citations as shown in Figure *20*.

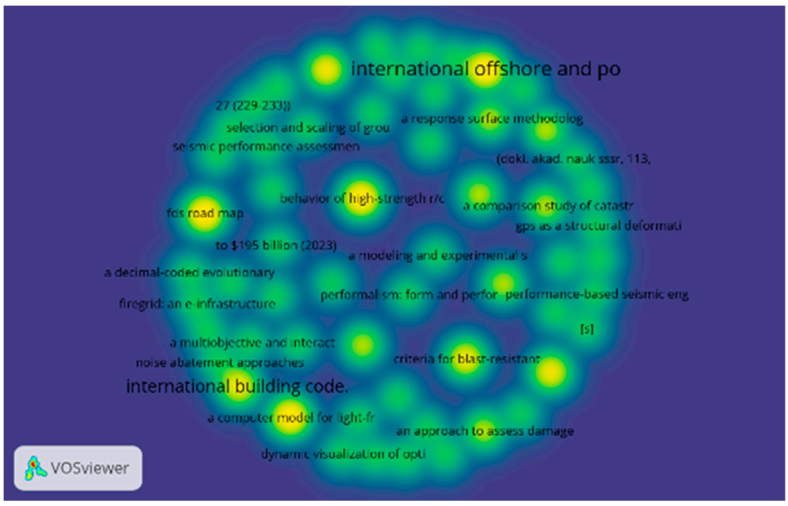


Figure 20. Visualization of Co-citation –cited source.

4.5.3. Category -V Co-Citation –Cited Author Case -3

Our result showed that under this category out of 61275 authors 1523 meet the thresholds.

For each of the 1523 authors the total strength of the co-citation links with other authors were calculated. The authors with the greatest total link strength were selected and ***priestley m.j.n.*** took the lead with 868 citations and 32230 total link strengths as shown in Figures 21 and 22.

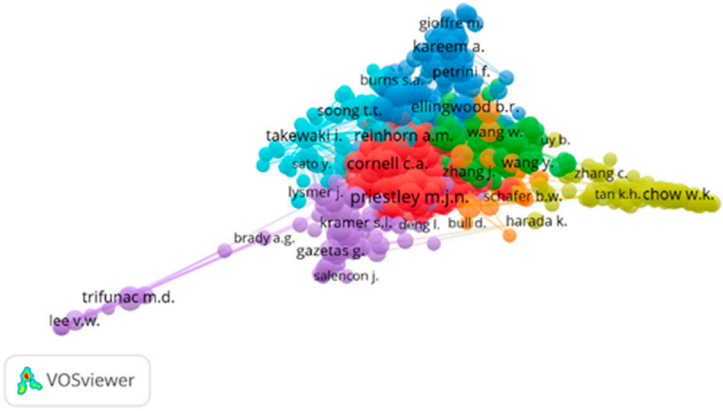
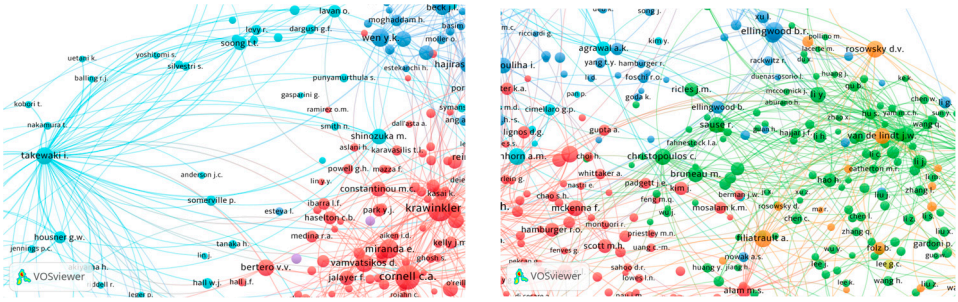


Figure 21. Visualization of Co-citation –cited author.



(a) (b)

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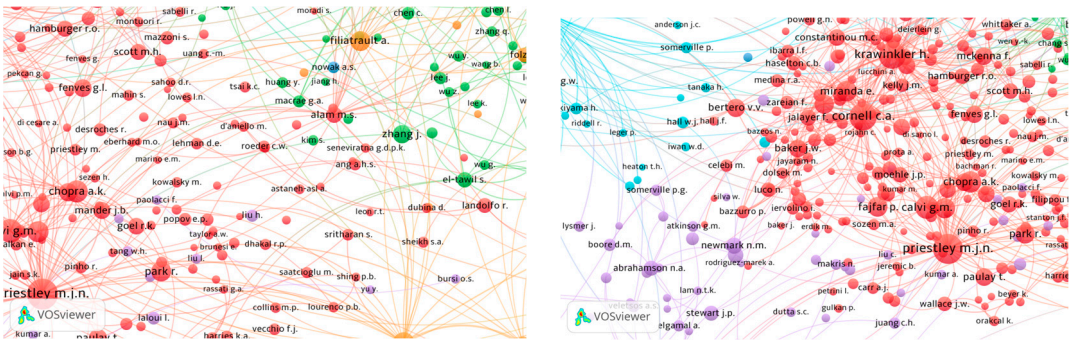

(c) (d)

Figure 22. Close-up view to the Category -IV Bibliographic coupling – Document's case -1. (a) Top-left quadrant. (b) Top-right quadrant. (c) Bottom-left quadrant. (d) Bottom-right quadrant.

5. Discussion

5.1. Research Interest in Publication Output and Growth

As shown in Figure 23, 3456 research articles were published over a 42-year period. The oldest publication dates back to 1981, and until 1995, there was no record of publication. Beginning in 1999, a strong interest in PBD research is indicated. The annual rate of growth (ARG) increased dramatically in 2007 and also in 2020 and 2022, which is one indication of the critical need for PBD.

Annual publications have since increased steadily, leading to a substantial increase in the cumulative publications produced. Therefore, the annual publication is expected to continue increasing. However, most of these articles are not freely available, and the user must pay to access the information.

There are vast fields of PBD research, and many research groups worldwide are involved in different areas. The subject area study showed that PBD studies focused mainly on engineering, as Appendix A - Table 4 shows.

Even though PBD is a multidisciplinary area, one of which has been classified under the subject area of Engineering. Results have also shown that the publications used in this research have been articles and conference papers written in English only. The search question string used in the Scopus database comprises various sources. Most papers are 54.5 % articles and 37.7% conference papers, which comprise almost 92.2 % of the whole analysis documents, as shown in Table 2.

Table 2. Documents as per Document type.

No	Document Type	Total No. of Document
1	Article	1894
2	Conference Paper	1311
3	Book Chapter	126
4	Review	81
5	Conference Review	26
6	Book	21
7	Editorial	7
8	Erratum	3
9	Note	3
10	Short Survey	2

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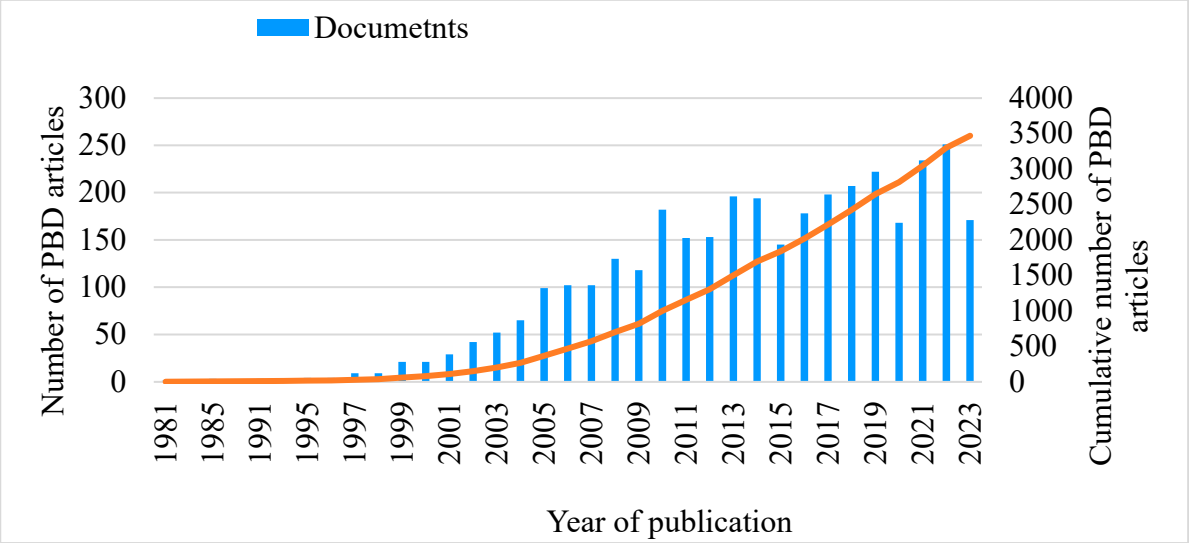

Figure 23. The annual and cumulative numbers of research articles on PBD indexed in Scopus Before 1981 until 2023.

5.2. Prefered Jouranals ,Leading Countries, Leading Organizations and International Institutions

Table 3 lists the 30 most prominent authors in PBD for publication range of 1981 -2023, as follows: China 1 author, United States 11 authors, United Kingdom 2 authors, Greece 3 authors, Iran 3 authors, Canada 3 authors, Italy 3 authors, India 1 author, New Zealand 1 author, Australia 1 author, and Israel 1 author.

Chow, W. K. from China has a record number of 629 articles, 43 h-index and 8,503 citations since 1985 from ***The Hong Kong Polytechnic University***. ***Kareem Ahsan*** placed in second place with 454 articles, 66 h- index and 14268 citations since 1979 from the ***University of Notre Dame, United States***. Next, ***van de Lindt & John W. are placed in third place with 366 articles, 44 h-index and 6310 citations since 1996 from Info Colorado State University, Fort Collins, United States. Torero and José Luis*** are placed in the 4th place with 324 articles, 46 h- index and 7242 citations since 1993, associated with ***University College London, United Kingdom*** as shown in Table 3.

Table 3. List of the 30 most prolific authors in the PBD research area.

No	Author	Scopus Author ID	Year of 1st publication	TP	h-index	TC	Current affiliation	Country
1	Chow, W. K.	7402281035	1985	629	43	8,503	The Hong Kong Polytechnic University, Info	China
2	Spence, Seymour M.J.	24723343400	2008	89	21	1377	University of Michigan, Ann Arbor	United States
3	Lagaros, Nikos D.	6603320949	1996	210	37	4510	National Technical University of Athens,	Greece

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4	van de Lindt, John W.	6701580121	1996	366	44	6310	Info Colorado State University, Fort Collins	United States
5	Rosowsky, David V.	7005964413	1991	215	40	5495	Kansas State University, Manhattan,	United States
6	Hajirasouliha, Iman	56016637100	2005	197	34	3790	The University of Sheffield, Sheffield,	United Kingdom
7	Gholizadeh, Saeed	8923656700	2003	64	26	1593	Urmia University, Urmia,	Iran
8	Ricles, James M.	7006226161	1982	254	56	9704	Lehigh University, Bethlehem	United States
9	Sause, Richard S.	7004943075	1984	251	52	9231	Lehigh University, Bethlehem,	United States
10	Christopoulos, Constantin	56846909500	2002	130	33	5242	University of Toronto, Toronto,	Canada
11	Papadrakakis, Manolis	7006108469	1980	267	47	6927	National Technical University of Athens,	Greece
12	Pei, Shiling	16031485700	2006	146	26	2407	Colorado School of Mines, Golden	United States
13	Behnam, Behrouz	55624757300	2012	51	12	450	Amirkabir University of Technology, Tehran	Iran
14	Beskos, Dimitrios E.	7006728767	1972	282	51	9252	University of Patras, Rio,	Greece
15	Gernay, Thomas	36460936600	2010	90	19	1315	Johns Hopkins University, Baltimore,	United States

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16	Petrini, Francesco	16304828000	2007	71	19	1584	Sapienza Università di Roma, Rome	Italy
17	Torero, José Luis	7004558676	1993	324	46	7242	University College London.	United Kingdom
18	Alam, Shahria Shahria	12241979000	2003	293	44	6688	The University of British Columbia, Vancouver,	Canada
19	Choudhury, Satyabrata S.	56704402900	2011	48	7	160	National Institute of Technology Silchar, Silchar,	India
20	Pampanin, Stefano	7801638248	1999	247	41	6778	University of Canterbury, Christchurch,	New Zealand
21	Kareem, Ahsan	35613461600	1979	454	66	14268	University of Notre Dame, Notre Dame	United States
22	Bontempi, Franco	25921277100	1991	99	21	1343	Sapienza Università di Roma, Rome,	Italy
23	Ciampoli, Marcello	7003543802	1992	39	14	939	Sapienza Università di Roma, Rome	Italy
24	Klemencic, Ron	16319078800	1995	40	10	348	Magnusson Klemencic Associates, Seattle,	United States
25	Pezeshk, Shahram	57203252619	1988	119	23	2204	University of Memphis, Memphis,	United States
26	Alipour, Alice A.	56414498100	2009	83	24	1709	Iowa State University, Ames,	United States
27	Estekanchi, Homayoon E.	6602609481	1995	113	26	2050	Sharif University of	Iran

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							Technology, Tehran	
28	Foschi, Ricardo O.	7006695812	1969	100	25	2000	The University of British Columbia, Vancouver,	Canada
29	Hidalgo, Juan Patricio	56903753000	2015	50	14	644	The University of Queensland, Brisbane,	Australia
							Technion - Israel	
30	Lavan, Oren	8700916800	2005	107	28	1834	Institute of Technology, Haifa,	Israel

As per our analysis result, the 30 most productive countries/territories in PBD research and overall citation as of September 27th ,2023, in the Scopus database are presented in Table 9. ***The United States takes the lead with 1076 total cited documents and 18160 grand total citations***. ***China*** comes to the 2nd place with 393 total cited documents and 3680 total citations. We found ***Canada*** in the 3rd place with 263 total cited documents and 4546 total citations. Lastly, we found ***Mexico*** in the 30th place with 20 cited documents and 266 total citations.

5.3. Author Keywords

Exploring the developments from 1981–2023 patterns in PBD research, the analysis used gathered all the keywords from the 3456 papers to study keywords and co-words. co-word networks were developed to demonstrate the relationships in visualised co-word networks in each field between the keywords and better understand changes to research interests over time. The study classified keywords that appeared in multiple times. According to the result in Table 8, the keyword 'performance-based ***design***' occurred 2100 times with a total link strength of 6619. In the second place, the keyword 'performance-based design' occurred 1042 times with a total link strength of 3486, and it has been noted that the effect of keyword representation also affected the output result of our analysis. The keyword '***seismic design***' occurred 970 times with a total kink strength of 4476. The keyword '***performance-based seismic design***' occurred 137 times with a total link strength of 753.

Table 4. The top 30 most used keywords in the PBD research.

No	id	keyword	occurrences	total link strength
1	10849	Performance based design	2100	6619
2	10974	Performance-based design	1042	3486
3	13194	Seismic design	970	4476
4	3513	Design	633	2400
5	14993	Structural design	615	2077
6	13415	Seismology	577	2673
7	4394	Earthquakes	503	2293

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8	12321	Reinforced concrete	451	1945
9	584	Architectural design	335	1361
10	5814	Fires	317	835
11	14953	Structural analysis	292	1282
12	13341	Seismic response	255	1356
13	10842	Performance assessment	249	1265
14	15029	Structural frames	248	1109
15	4329	Earthquake engineering	233	1165
16	1422	Buildings	215	922
17	13301	Seismic performance	213	1155
18	15477	Tall buildings	196	818
19	12762	Risk assessment	195	711
20	2536	Concretes	185	799
21	10474	Optimization	183	705
22	5578	Finite element method	182	678
23	2446	Concrete construction	176	805
24	6775	Hazards	170	765
25	15102	Structural response	166	893
26	3415	Deformation	164	655
27	1798	Civil engineering	161	673
28	13394	Seismic waves	145	866
29	2436	Concrete buildings	144	778
30	10869	Performance based seismic design	137	753

5.4. Concept and Terminology

From the total 3456 documents our findings showed that PBD's most frequently identified keyword was '**performance based design'** with occurrence of 2100 times and 6619 total links strengths to other keywords as shown in Table 4. Also, it has been noted that using general terms such as ' seismic design' 970 incidents, with 4476 links strengths, 'design' 633 incidents with 240 total link strength and 'deformation' 164 incidents, with 655 total link strength and 'structural design' 615 incidents with 2077 total link strengths.

We also found some interesting keywords related to PBD publications. For example, 'structural response' 166 incidents, with 893 total link strengths. 'Seismic waves' 145 incidents with 866 total link strengths. Similarly, the word 'hazards' 170 incidences with 765 total link strength and other multiple words were found as shown in Table 4 and out of a total of 6956 author keywords, 381author keywords were used and meet the threshold, and used for the analysis for VOSviewer mapping by limiting a minimum requirement of 5 occurrences per analysis.

5.5. Topics of Interests

PBD methodology is analyzed and it is an evolving technology and the keyword 'performance based design' have occurred 2100 times with a link strength of 6619 as shown in Table *4*.

The bubble width reflects the keyword frequency count, while the row thickness shows the keyword cooccurrence magnitude. Different research areas have been described and presented in the statistics. During the period 1981-2023, PBD work focused on these broad areas.

The top 22 most productive journals on PBD research with their most cited articles are presented in Table 5 and as per the analysis result ***the journal of Engineering structures*** found in the 1st place

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with the most cited article title '**Novel visual crack width measurement based on backbone double-scale features for improved detection automation'** published by Elsevier Ltd. Which was cited 70 times as of October 2nd ,2023 as shown in Table 5.

Table 5. The top 22 most productive journals on PBD research with their most cited article.

Journal	Total Publication (TP) (%)	Total Citation (TC)	Total Publication (TP)in Engineering subject area	Cite Score 2023	The most cited article (reference)	No of times cited	Publisher
Engineering Structures	1569	52429	153	9.2	Novel visual crack width measurement based on backbone double-scale features for improved detection automation	70	Elsevier Ltd
Earthquake Engineering and Structural Dynamics	255	4166	81	6.6	Reinforced moment-resisting glulam bolted connection with coupled long steel rod with screwheads for modern timber frame structures	16	John Wiley and Sons Ltd
Soil Dynamics and Earthquake Engineering	587	13787	61	7.5	Near-fault pulse seismic ductility spectra for bridge columns based on machine learning	34	Elsevier Ltd
Geotechnical, Geological and	252	118	56	0.4	Seismic Response of	6	Springer Science and

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Earthquake Engineering					Masonry Building Aggregates in Historic Centres: Observations, Analyses and Tests		Business Media B.V.
Journal of Constructional Steel Research	485	14326	49	7.3	Self-centring damper with multi-energy-dissipation mechanisms: Insights and structural seismic demand perspective	35	Elsevier Ltd
Procedia Engineering	399	23216	48	4	Wildland Forest Fire Smoke Detection Based on Faster R-CNN using Synthetic Smoke Images	182	Elsevier Ltd
Bulletin of Earthquake Engineering	265	8102	45	8.3	Seismic fragility assessment of geotechnical seismic isolation (GSI) for bridge configuration	18	Springer Science and Business Media B.V.
Fire Safety Journal	206	4168	45	5.7	Residual compressive strength of concrete after exposure to high temperatures:	4	Elsevier Ltd

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Journal of Structural Engineering	225	7932	42	6.5	A review and probabilistic models Stub Column Behavior of Concrete-Filled Cold-Formed Steel Semi-Oval Sections	22	American Society of Civil Engineers (ASCE)
Lecture Notes in Civil Engineering	5117	8255	41	0.7	Performance of RCC Column Retrofitted with CFRP Wrappings and the Wrappings with Steel Angle-Batten Jacketing Under Blast Loading	15	Springer Science and Business Media Deutschland GmbH
Journal of Earthquake Engineering	256	3175	40	5.1	Improved Hybrid Method for the Generation of Ground Motions Compatible with the Multi-Damping Design Spectra	18	Taylor and Francis Ltd.
Structural Design of Tall and Special Buildings	51	1885	38	5.4	Numerical analysis on mechanical behavior of steel-concrete composite beams under fire	2	John Wiley and Sons Ltd

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Structures	1544	15378	36	4.7	Efficient training of two ANNs using four meta-heuristic algorithms for predicting the FRP strength	95	Elsevier Ltd
Proceedings of the International Conference on Education and Research in Computer Aided Architectural Design in Europe	91	496	35	0.8	41st Conference on Education and Research in Computer Aided Architectural Design in Europe, eCAADe 2023	0	Education and research in Computer Aided Architectural Design in Europe
Journal of Building Engineering	2345	38856	34	8.3	Self-centring hybrid-steel-frames employing energy dissipation sequences: Insights and inelastic seismic demand model	43	Elsevier Ltd
Journal of structural Engineering	258	3175	33	5.1	Improved Hybrid Method for the Generation of Ground Motions Compatible with the Multi-Damping Design Spectra	18	Taylor and Francis Ltd.

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Geotechnical Special Publication	436	1194	30	0.8	Durability and recuperative properties of lime stabilized soils	2	American Society of Civil Engineers (ASCE)
Advances in Structural Engineering	171	4545	27	4.6	Experimental investigation on the bond performance of sea sand coral concrete with FRP bar reinforcement for marine environments	31	SAGE Publications Inc.
ACI Structural Journal	97	1815	25	3.3	Transition between Shear and Punching in Reinforced Concrete Slabs: Review and Predictions with ACI Code Expressions	4	American Concrete Institute
Earthquake and Structures	48	1253	21	3.2	Simplified analytical solution of tunnel cross section under oblique incident SH wave in layered ground	2	Techno-Press
Journal of Performance of Constructed Facilities	81	2430	21	4.8	A State-of-the-Practice Review of Three-Dimensional Laser Scanning Technology for	8	American Society of Civil Engineers (ASCE)

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Earthquake Spectra	98	3208	20	7.1	Tunnel Distress Monitoring Multi-criteria decision-making approach for optimal seismic/energy retrofitting of existing buildings	7	SAGE Publications Inc.

As per our analysis result the 30 most productive research institutions in the PBD subject area versus documents whole institution and affiliation research work is presented in Appendix A-Table *10*. According to the analysis result**, Tongji University from China has been found in the number one position with a total documents whole institution of 135,714 and affiliation only 124,656, and in the documents by subject area of engineering,** a total document of 55,678.

6. Limitation of Study

The results of the search may not cover all studies related to PBD available on Scopus by restricting the search of TITLE-ABS-KEY (“performance based design*.”) AND (LIMIT-TO (LANGUAGE, "English”)). This query string's output was 3456 documents.in titles and abstracts. It is proposed to Compare future studies' performance of Several databases, such as the Web of Science. For example, the Web of Science search results automatically show the most popular articles in the field through a feature called ' hot paper, ' A feature Scopus lacks. The hot paper feature shows main papers Recognized as soon as published, Represented by a fast and large number of quotes. Bibliometric analysis using multiple data sources will be useful for a more comprehensive study.

In the PBD fields, the database was limited to just the above string query for all PBD studies; the patterns and trends produced in the study may not apply between 1981 and 2023. For better generalizability, more scientific publications should be included in future research over a longer study period. To identify new issues and trends related to this research topic, it is important to replicate or repeat existing quantitative study studies on PBD given an emerging area of research. However, the notion of clusters as the theoretical foundations of PBD work could be skewed because of the weaknesses of the bibliometric study. However, future research should develop an innovative classification tool to examine work trends and advances further. However, this research paper used only one VOSviewer program, so specific bibliometric analysis tools could be used for future studies.

7. Conclusions

This analysis presented an overview of developments in PBD research based on 3456 Scopus database publications since the last 42 years, publication growth has been strong, and it is expected to increase further.

We have discovered a huge number of publications and strong international collaborations in countries such as the United States and China. These institutions may offer incentives to researchers from other countries like Greece and Iran to expand their research collaborations. We also addressed many fields that are well explored at the moment, such as engineering and earth sciences. We also discussed several newly researched areas with PBD, such as seismic design and earthquake which could be potential hot topics for future studies.

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In this paper, we provided a supplement evaluation on the global research trends in PBD studies, by summarizing the patterns of authorship, journal and subject categories, geographic and institutional distributions, and temporal evolutions of keyword frequencies. Our analysis suggested that there has been steady growth in the scientific outputs in PBD research and confirms the dynamic collaborations in this field. This paper could also be useful to inform decisions on curriculum development, library subscription, and research performance evaluation. Because bibliometric findings depended on selected bibliographic materials, our analysis and associated interpretations only aim at evaluating research progress based on the selected Scopus databases.

Here is a summary of major findings from our bibliometric analysis:

• Research output descriptors suggested a solid development in PBD research, in terms of increasing scientific production and research collaboration.

• The four most common categories were Performance based design, seismic design, seismology and earthquakes, civil engineering, and geological engineering, implying an applied tradition in PBD studies. Performance based design has the largest field showing its substantial influence in earthquake researches.

• The uneven geographic distribution of PBD publications is correlated with individual countries proneness to earthquakes.

• The US and China attained a leading position in PBD research by contributing the largest share of single-country and internationally collaborated articles.

• Similarly Table 9 shows that Tongji University and The Hong Kong Polytechnic University(China), National Technical University of Athens (Greece), University of Michigan, Ann Arbor (US), Sapienza Università di Roma (Italy), University of Canterbury (New Zealand), University of California, Berkeley (US), The University of Edinburgh(Scotland) , Kyoto University (Japan), The University of British Columbia (Canada), Lehigh University (US), Università degli Studi di Napoli Federico II (Italy), University of Illinois Urbana-Champaign (US), State Key Laboratory of Disaster Reduction in Civil Engineering (China) , Colorado State University (US), The University of Queensland (Australia) , The University of Sheffield (UK), Ministry of Education of the People's Republic of China (China), Georgia Institute of Technology (US), Texas A&M University (US), Sharif University of Technology (Iran), University of Washington (US), Oregon State University (US), Oregon State University (US), University of Toronto (Canada), The University of Tokyo (Japan), University at Buffalo, The State University of New York (US), Arup Group Limited (UK), Stanford University (UK), Stanford University (US), ETH Zürich (Switzerland),and Johns Hopkins University (US). It has to be noted that this result was found in the bases of the whole institutions and affiliation only documents and subject area publication document bases, ***hence these universities topped the list of productive institutions in PBD research.***

• The most commonly used keywords appeared in the articles were performance based design, seismic design, structural design, seismology, earthquakes, reinforced concrete, architectural design, structural analysis, seismic response, performance assessment, structural frames, earthquake engineering, buildings, seismic performance, tall buildings, risk assessment, concretes,optimization,finite element method, concrete construction, hazards, structural response, deformation, civil engineering, seismic waves, concrete buildings, and performance based seismic design have received clearly increasing interests. The critical research ideas identified in this paper also includes; **the effect of fiber reinforced polymer in performance based design of structures approach and the coupling of sequential analysis in PBD methodologies.**

• In the category-I Co- Authorship – Countries case-3 collaboration network analysis, it is evident that United States holds an absolute core position in the field of performance based design research globally and has connections with other countries. The proportion of publications authored by US scholars is as high as 1076 documents with a total citation of as high as 18137. In addition to that in the category II; co-occurrence-All keywords case-1, co-occurrence-author keywords case-2, co-occurrence-index keywords case-3 analysis it was found out that the key word **'performance based design'** is the most frequently used keyword in most scholarly articles in all the three analyses result.

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Similarly, the category III- citation – countries case 4 analysis result indicated that US has the greatest citation total link strength with other countries and UK found in the second position in this category.

• As per PART -5 Co-citation-cited references case-1 the total strength of the co-citation links with other cited references were calculated. The cited references with the greatest total link strength were selected and **prestandard and commentary for the seismic rehabilitation of building 2000** paper leads this category by 135 citations and 150 total link strengths. Similarly in the category V-Co-citation – cited sources case 2 analysis result the sources with the greatest total link strength were calculated and **International offshore and polar engineering conference** took the lead in this category. In the same way Co-citation-cited author case -3 analysis result the authors with the greatest total link strength were selected and ***priestley m.j.n***. took the lead with 868 citations and 32230 total link strengths.

• In the citation analysis the top most productive journals on PBD research were identified and ***journal of Engineering Structures*** was found the most productive journal with a total publication of 1569 articles and a total citation of 52429. The most cited article was ***Novel visual crack width measurement based on backbone double-scale features for improved detection automation*** which was published by **Elsevier Ltd**. In the same way ***Journal of Earthquake Engineering and Structural Dynamics*** was found in the 2nd place in this category and the most cited article was ***Reinforced moment-resisting glulam bolted connection with coupled long steel rod with screwheads for modern timber frame structures*** published by **John Wiley and Sons Ltd**. ***The journal of Soil Dynamics and Earthquake Engineering*** was found in the 3rd place and the most cited article was ***Near-fault pulse seismic ductility spectra for bridge columns based on machine learning*** published by **Elsevier Ltd.** ***Journal of Geotechnical Geological and Earthquake Engineering*** was found in the 4th place and the most cited article ***was Seismic Response of Masonry Building Aggregates in Historic Centres: Observations, Analyses and Tests*** published by **Springer Science and Business Media B.V.** . ***The journal of Earthquake spectra*** was found at 22nd position and the most cited article was ***Monitoring Multi-criteria decision-making approach for optimal seismic/energy retrofitting of existing buildings*** published **by SAGE Publications Inc.** so as per the result the most active journals in the research of PBD was identified.

• A small group of prolific authors contributed to a significant share of publications in PBD research, and 30 authors made the top cited and most published lists simultaneously. Several collaborative clusters of authors were also visualized. As per the analysis result the 30 most prolific authors in the PBD research area was identified and Chow, W. K. from China current affiliation with **The Hong Kong Polytechnic University** took the lead with a total publication of 629 and the h-index of 43. Authors from the United States Spence and Seymour M.J. affiliation with **University of Michigan Ann Arbor** placed in the second place. In the same way Authors from Greece; Lagaros and Nikos D. current affiliation with **National Technical University of Athens** placed at 3rd position. Authors from Israil; Lavan and Oren currently affiliation with **Israel Institute of Technology,** Haifa was found in the 30th position. Hence the analysis result indicated the most 30 most active authors in the PBD research.

Overall, this study provides a comprehensive overview of the research on performance based design and identifies the key research topics and future directions for further exploration in PBD research area.

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Appendix A

Table 6. Verified selected organisation.

Id	Organisation	Documents	Citations	Total link strength
680	College of civil engineering, Tongji university, shanghai, 200092, china	7	34	0
1070	Department of civil and environmental engineering, Lehigh University, Bethlehem, 18015, pa, united states	6	81	0
1204	Department of civil and environmental engineering, university of Michigan, Ann Arbor, 48109, mi, united states	10	125	0
1229	Department of civil and environmental engineering, university of washington, seattle, wa, united states	5	97	0
1256	Department of civil and natural resources engineering, university of canterbury, christchurch, new zealand	12	238	0
1267	Department of civil and structural engineering, the university of sheffield, sheffield, united kingdom	8	180	1
1369	Department of civil engineering, colorado state university, fort collins, co, united states	6	23	0
1392	Department of civil engineering, faculty of engineering, university of qom, qom, iran	7	42	0
1562	Department of civil engineering, national taiwan university, taipei, taiwan	6	183	3
1621	Department of civil engineering, sharif university of technology, tehran, iran	13	210	3
1677	Department of civil engineering, university of british columbia, vancouver, bc, canada	7	126	0
1685	Department of civil engineering, university of canterbury, christchurch, new zealand	5	145	0
1722	Department of civil engineering, university of patras, patras, greece	6	2	2
1773	Department of civil engineering, urmia university, urmia, iran	17	400	0
2148	Department of structural engineering, tongji university, shanghai, 200092, china	6	139	2
2186	Department of structures for engineering and architecture, university of naples federico ii, via claudio 21, naples, 80125, italy	6	133	0

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2339	Dept. of civil and environmental engineering, univ. of Michigan, ann arbor, 48109, mi, united states	9	225	5
2377	Dept. of civil Eng., univ. of southern California, los angels, 90089, ca, united states	5	60	0
2941	Federal highway administration, Baltimore, 21201, md, united states	5	96	5
3055	Georgia institute of technology, Atlanta, ga, united states	7	26	0
3057	Georgia institute of technology, united states	5	39	0
3899	National center for research on earthquake engineering, Taipei, Taiwan	5	91	3
4212	Research centre for fire engineering, department of building services engineering, Hong Kong polytechnic university, Hong Kong.	7	36	0
4594	School of engineering, the university of British Columbia, Kelowna, bc, Canada	5	98	1
4838	State key laboratory of disaster reduction in civil engineering, tongji university, shanghai, 200092, china	7	212	2
4839	State key laboratory of disaster reduction in civil engineering, tongji university, shanghai, china	6	33	3

Table 7. Verified selected countries.

id	country	documents	citations	total link strength
6	Algeria	6	29	3
9	Argentina	10	409	10
13	Australia	126	2313	91
14	Austria	19	192	13
17	Bangladesh	5	7	4
18	Belgium	35	366	28
21	Brazil	24	434	27
24	canada	263	4539	132
27	Chile	20	272	16
28	china	391	3610	172
31	Colombia	14	18	13
36	Croatia	13	127	15
37	Cyprus	12	237	10
38	Czech Republic	11	119	11
39	Denmark	21	144	17
43	Egypt	21	97	10
47	Finland	10	274	10
49	France	55	903	40

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51	Germany	64	457	52
53	greece	96	2189	51
55	Hong Kong	88	1546	54
61	India	160	1332	30
62	Indonesia	23	37	8
64	iran	196	2582	56
65	Iraq	6	33	6
66	Ireland	9	66	3
67	Israel	23	358	9
68	italy	240	4662	121
69	Japan	238	2471	70
70	Jordan	5	4	3
73	Lebanon	5	8	2
77	Malaysia	19	112	9
79	Mexico	20	266	9
81	Netherlands	29	315	32
82	new zealand	67	1462	59
86	Norway	13	83	14
95	Poland	8	77	2
96	Portugal	45	791	32
101	Romania	9	83	3
106	Serbia	5	68	9
107	Singapore	31	884	20
109	Slovenia	9	88	7
111	south Africa	11	269	7
112	south Korea	79	733	38
113	Spain	36	497	22
121	Sweden	37	471	32
122	Switzerland	43	696	34
124	taiwan	63	669	20
126	Thailand	17	450	10
129	turkey	93	842	41
131	United Arab Emirates	11	36	6
132	United Kingdom	250	3936	168
133	united states	1076	18137	331
6	Algeria	6	29	3
9	Argentina	10	409	10
13	Australia	126	2313	91
14	Austria	19	192	13
17	Bangladesh	5	7	4

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24	canada	263	4539	132
27	Chile	20	272	16
28	china	391	3610	172
31	Colombia	14	18	13
36	Croatia	13	127	15
37	Cyprus	12	237	10
38	Czech Republic	11	119	11
39	Denmark	21	144	17
43	Egypt	21	97	10
47	Finland	10	274	10
49	France	55	903	40
51	Germany	64	457	52
53	greece	96	2189	51
55	Hong Kong	88	1546	54
61	India	160	1332	30
62	Indonesia	23	37	8
64	iran	196	2582	56
65	Iraq	6	33	6
66	Ireland	9	66	3
67	Israel	23	358	9
68	italy	240	4662	121
69	Japan	238	2471	70
70	Jordan	5	4	3
73	Lebanon	5	8	2
77	Malaysia	19	112	9
79	Mexico	20	266	9
81	Netherlands	29	315	32
82	new zealand	67	1462	59
86	Norway	13	83	14
95	Poland	8	77	2
96	Portugal	45	791	32
101	Romania	9	83	3
106	Serbia	5	68	9
107	Singapore	31	884	20
109	Slovenia	9	88	7
111	south Africa	11	269	7
112	south Korea	79	733	38
113	Spain	36	497	22
121	Sweden	37	471	32

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122	Switzerland	43	696	34
124	taiwan	63	669	20
126	Thailand	17	450	10
129	turkey	93	842	41
131	United Arab Emirates	11	36	6
132	United Kingdom	250	3936	168
133	united states	1076	18137	331

Table 8. Documents as per PBD subject Area.

No	Subject Area	Documents
1	Engineering	2799
2	Earth&and planetary Sciences	686
3	Materials Science	585
4	Computer Science	343
5	Environmental Science	242
6	Social Sciences	210
7	Mathematics	173
8	Physics and Astronomy	156
9	Energy	143
10	Agricultural and Biological Sciences	137
11	Chemistry	113
12	Chemical Engineering	55
13	Arts and Humanities	50
14	Business, Managment and Accounting	29
15	Medicine	12
16	Decision Sciences	8
17	Multidisciplinary	8
18	Biochemistry, Genetics and	4

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	Molecular Biology	
19	Health Professions	4
20	Psychology	3
21	Neuroscience	1

Table 9. The 30 most productive countries/territories in PBD research and overall citation as of Sep 27th 2023 in Scopus Database.

No	Country	Total cited Documents	Grande Total Citation
1	United States	1076	18160
2	China	393	3680
3	Canada	263	4546
4	United Kingdom	252	4031
5	Italy	242	4676
6	Japan	238	2472
7	Iran	196	2582
8	India	161	1332
9	Australia	126	2314
10	Greece	96	2190
11	Turkey	93	842
12	South Korea	79	735
13	New Zealand	67	1463
14	Germany	64	460
15	Taiwan	63	669
16	France	55	904
17	Portugal	45	791
18	Switzerland	43	699
19	Sweden	38	491
20	Spain	36	500
21	Belgium	35	366
22	Singapore	31	887
23	Netherlands	29	315
24	Brazil	25	434
25	Indonesia	23	37
26	Israel	23	361
27	Egypt	22	97
28	Denmark	21	146
29	Chile	20	272
30	Mexico	20	266

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Table 10. The 30 most productive research institutions in the PBD subject area vs Documents whole institution and affiliation re-search work.

No	Affiliation details	Affiliation ID	Documents, whole institution	Documents, affiliation only	Authors	Documents by subject area	Total documents by subject area	Country
1	Tongji University	60073652	135,714	124,656	39,168	Engineering	55678	China
2	The Hong Kong Polytechnic University	60008928	96,466	94,715	17,143	Engineering	38,360	China
3	National Technical University of Athens	60002947	48,354	47,093	8,546	Engineering	21353	Greece
4	University of Michigan, Ann Arbor	60025778	382,167	313,616	52,476	Engineering	52,549	United States
5	Sapienza Università di Roma	60032350	216,532	213,139	39,203	Engineering	27,202	Italy
6	University of Canterbury	60020585	38,338	38,260	7,235	Engineering	7274	New Zealand
7	University of California, Berkeley	60025038	302,245	295,744	44,499	Engineering	68,429	United States
8	The University of	60027272	189,664	168,191	24,736	Engineering	15254	Scotland

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9	Edinburgh Kyoto University	60011001	270,212	253,270	44,180	Engineering	41751	Japan
10	The University of British Columbia	60010365	253,824	236,085	46,569	Engineering	25983	Canada
11	Lehigh University	60000060	30,416	30,090	6,721	Engineering	10248	United States
12	Università degli Studi di Napoli Federico II	60017293	140,638	136,179	23,800	Engineering	23,498	Italy
13	University of Illinois Urbana-Champaign	60000745	254,617	250,028	48,562	Engineering	53952	United States
14	State Key Laboratory of Disaster Reduction in Civil Engineering	60129231	6,045	6,045	881	Engineering	4997	China
15	Colorado State University	60009226	90,332	84,786	18,420	Engineering	11360	United States
16	The University of	60031004	195,229	194,031	32,238	Engineering	20433	Australia

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17	Queensland The University of Sheffield	60001881	133,397	126,273	21,172	Engineering	25057	United Kingdom
18	Ministry of Education of the People's Republic of China	60001604	779,855	708,010	30,192	Engineering	220842	China
19	Georgia Institute of Technology	60019647	145,588	141,976	22,729	Engineering	63,489	United States
20	Texas A&M University	60020547	205,522	186,581	36,030	Engineering	45,214	United States
21	Sharif University of Technology	60027666	36,913	36,678	8,684	Engineering	18,602	Iran
22	University of Washington	60015481	346,158	307,146	53,718	Engineering	27,287	United States
23	Oregon State University	60013402	82,314	81,394	17,652	Engineering	12,347	United States
24	University of Toronto	60016849	418,086	387,554	67,114	Engineering	36730	Canada
25	The University	60025272	390,992	348,064	59,007	Engineering	70390	Japan

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	y of Tokyo							
	Universit y at Buffalo,							
26	The State Universit y of New York	60032083	108,662	105,982	22,441	Engineeri ng	15503	United States
27	Arup Group Limited	60099927	3,822	2,857	1,669	Engineeri ng	2012	United Kingdom
28	Stanford Universit y	60012708	383,381	281,197	40,435	Engineeri ng	49671	United States
29	ETH Zürich	60025858	189,606	187,152	34,770	Engineeri ng	39397	Switzerla nd
30	Johns Hopkins Universit y	60005248	367,944	191,956	26,923	Engineeri ng	20117	United States

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