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A scientometric study and a bibliometric review of the literature on the design and construction of semi-flexible pavement

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ABSTRACT

In last years, a new type of pavement has gained popularity, this type is called Semi-Flexible Pavement (SFP). It consists of porous asphalt with high air voids between (25-35) % filled with cementitious grout materials. This type of pavement substance offers substantial advantages over both common types of pavements (concrete and flexible) such as good resistance to rutting and durability. SFP is considered an alternative pavement to exceed the drawbacks that occur for both flexible and concrete pavements. SFP has good features against permanent deformation, oil spillage, and fatigue resistance. Previous studies have shown that it can be used in a variety of applications such as highways, motorways, bridge deck pavement, tunnels, industrial areas with industrial equipment traffic, airport aprons, and stations. The goal of this research is to identify and compile the most significant research papers using the Web of Science (WOS), analyze the data using the VOS viewer software, as well as learn which countries and institutions had published the most articles relating to the subject of cementitious grout material as it relates to semi-flexible. It was also done to learn more about the authors and their collaboration. In addition to knowing the keywords that will aid researchers in their research on this topic, using these studies to better understand the elements that affect how well semi-flexible mixtures and grouts perform such as porous asphalt Mixture gradation and grout material components.

1. Introduction

The main purpose of highway pavement is to disperse the applied vehicle loads to the subgrade. A highway pavement is a structure made up of layers of processed materials overlaid above the natural soil subgrade. The pavement construction must be able to offer a surface with good riding quality, sufficient skid resistance, good light-reflecting properties, and low noise pollution. The ultimate goal is to make sure that transmitted stresses caused by wheel loads are sufficiently decreased so that they won't surpass the subgrade's bearing capability. The two primary types of pavement used in highway construction are (flexible and concrete) pavements. Flexible pavements are those which are surfaced with asphalt materials [1]. Whereas rigid pavements are surfaced with Portland cement concrete slabs that are placed directly on the subgrade or a single layer of granular or stabilized soil [2]. Flexible pavement is a common kind of pavement because it has low construction costs, excellent riding quality, and simplicity of design,

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and offers a lot of stability and durability as well as good resistance to water damage. But the recent trend of more heavy traffic and bad environmental conditions has made it more likely to have problems like fatigue, cracks, ruts, and low-temperature cracking. Most damage to flexible pavement comes from fatigue and rutting [3-4]. These may have an impact on both its performance and useful life. On the other hand, concrete pavements are also recommended since they are more durable and allow for longer design lives. They can be directly applied over weak soils and provide good visibility at night. Concrete pavements have been used in a variety of specific applications. Many airports all around the world depend on concrete pavements, particularly when big aircraft are involved and while building the touchdown zone [5]. On the other hand, rigid pavement can sustain significant traffic loads, but it has a significantly higher initial cost, may exhibit increased roughness and noise owing to the presence of transverse joints, and as a result, offers less comfort when riding [6]. Due to the slow curing of concrete, concrete pavement installation and traffic opening generally take longer, so rigid pavement also has disadvantages. As a result, in recent decades, a novel hybrid type of pavement has become increasingly popular to address the aforementioned problems and enhance the performance of pavements, which is the major topic of this review study. It is known as semi-flexible pavement because the surface layer contains a semi-flexible material. It can combine the best characteristics of rigid and flexible pavements. Grouted macadam, also known as semi-flexible pavement surfacing, is described as having an impermeable surface, a long operational life, great rutting resistance, and high durability [7]. A semi-flexible material that is typically utilized as the top course of specialized pavements (industrial floors, distribution centers, harbors, airport pavements). They are made of an asphalt mixture and a layer of cementitious grout. Macadam with grout, essentially an open-graded asphalt mixture with a skeleton with voids (20–25%), makes up the top layer of the semi-flexible pavement. The flexibility and lack of joints of asphalt pavements are combined with the high static carrying capacity, effective rut resistance, and durability of concrete pavements in this hybrid material [8]. The article focuses on identifying semi-flexible paving, describing its construction and design, and showing the factors that influence semi-flexible pavement performance. It also aims to find and collect the most important research papers by using the Web of Science (WOS) and then using the VOS viewer program to analyze the data. These data involved countries and journals that have written about semi-flexible pavement, and to learn more about the authors and how they work together. In addition to knowing the search keywords that make academic research on this topic easier, you can use these studies to learn more about the factors that affect how well semi-flexible mixtures and grouts perform, such as the gradation of porous asphalt mixtures and the components of grout materials.

2. History of semi-flexible pavement

The semi-flexible process was first developed in France in the 1950s to protect asphalt and concrete surface courses from the threat of waste oils and fuel, [9]. As a more affordable alternative to Portland cement concrete, this procedure, known as "Salviacim", was further developed by the French construction firm Jean Lefebvre Enterprises [10], after the Salviacim procedure was effective. It was used in a variety of countries, including (Saudi Arabia, the United Kingdom, South Africa, Japan, and Australia) [11]. Since then, comparable items have been utilized with various names depending on the region. As a result, it was referred to as resin-modified pavement (RMP) in the United States. RMP can be applied to both the construction of new pavement and the restoration of old pavement construction. The RMP method has been used in several applications across the globe, including airport and vehicle roads, industrial and warehouse flooring, fuel depots and commercial petrol stations, city plazas and malls, transport hubs, and port facilities [12]. Other countries in Europe, Africa, America, and the Pacific Islands carried out SFP construction [13]. Recently, SFP has been utilized as the surface of highways, motorways, bridge decks, tunnels, industrial areas with heavy machinery activity, airport aprons (with a high potential for chemical and fuel spills), and stations [14] in both European nations such as Germany, England, Italy, or the Netherlands and Asian nations such as China, Malaysia, Singapore, and India [15]. It is often categorized as "grouted macadam," while some authors have also used the term "combi-layer [16].

3. Application fields

The most common fields of application for these pavements, were heavy-duty areas, such as industrial floors, factories, distribution centers, workshops, harbors, roads, crosswalks, bus terminals, parking lots with high traffic, airport pavements, holding bays, hangar pavements, cargo centers, and other areas subjected to heavy traffic due to their high bearing capacity and rut resistance, [17]. SFP covering 165,000 square meters was built between 1988 and 2000 at Copenhagen Airport and the Dutch city of Delft's main train terminal, [18].

4. Constitution of grouted macadams

As a surface course, a typical semi-flexible pavement layer comprises cementitious grout and an asphalt mixture. Grouted macadams essentially consist of an open-graded asphalt mixture (often single-sized), which creates the framework into which a cementitious grout is injected. The finished product incorporates some of the best features of concrete and asphalt pavements, including concrete's high static carrying capacity and wears resistance and asphalt's flexibility and lack of joints [19-22] . The construction of SFP occurs in two stages. The first stage involves constructing porous asphalt pavement with 20–35% air voids.

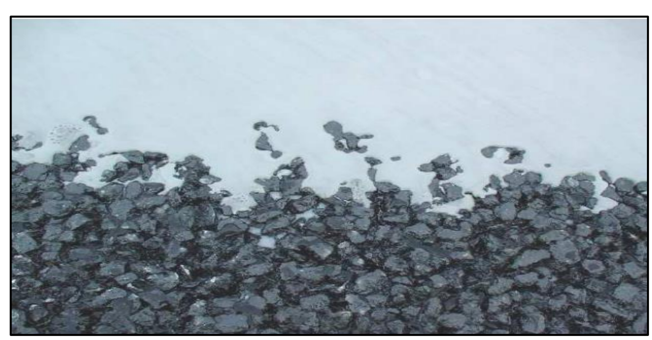

Figure 1. Cementitious grout during the process of penetrating the voids of a porous asphalt skeleton [24]

In the second stage, the voids in asphalt mixes are filled with grouts (i.e., cement mortar or cement paste) [23], and the mixture is then cured over a period that is dependent on a light steel roller that may be employed in the vibration mode to ensure that the spaces of the asphalt are filled with the grout, as shown in Figures 1 and 2. SFP's characteristics depend on the type of powder used to generate the grout and the producer's specifications.

The surface can be treated to enhance its qualities, including skid resistance, durability, and attractiveness after the grout compounds fill the spaces.

Figure 2. SFP slabs after compaction (a); open grade mixture slab after compaction (b); open grade slabs after filling with cement mortar (c); cores extracted from a grouted slab (d) [25].

5. Factors influencing the performance of grouts and semi-flexible mixtures

The structure of the porous bitumen and the cementitious grouting materials that make up the mixture affects how well the semi-flexible layer works. Several of the factors that affect the performance of semi-flexible layers are identified and discussed below:

5.1 Porous Asphalt Mixture Gradation

For decades, porous paving technology has been used, which consists of a mixture containing air voids ranging from 18 to 22 percent.[26], as shown in Figure 3. This technique is known as the open-graded friction course (OGFC)" when used as a surface layer, Various other names for it include Porous Asphalt (PA), Porous Friction Course (PFC), and Permeable European Mix (PEM), [27-30]. PA is a type of asphalt that contains little or no fine aggregate. The reduced quantity of fines in the asphalt mix creates interconnected, stable air pockets that allow water to flow through the mix. Porous asphalt is used in two main paving applications all over the world: wear courses on high-speed roadways and porous pavements for drainage systems. A thin layer of porous asphalt ranging in thickness from 19 to 50 mm is applied as a wearing course over a conventional impermeable pavement surface, [31]. The Federal Highway Administration (FHWA) issued the initial design of these mixtures in 1974, and it was modified again in 1980 and 1990, [32]. PA mixes have lots of advantages, including reduced spray and splash, reduced hydroplaning issues, improved surface frictional resistance, improved night visibility during rainy conditions, and reduced tire noise issues, [33-36]. The qualities of the final mix perform significantly depending on the aggregate gradation selected. A single-sized aggregate is often used to create porous asphalt mixtures in an open-graded asphalt gradation. Typically, (90-95 percent of coarse aggregate), (4% percent of fine sand), and (2 percent of filler powder) are used to create open-graded asphalt mixtures for semi-flexible pavement applications, 37-40]. The asphalt skeleton is an important and little-understood component of semi-flexible pavements, and it plays a critical role in evaluating the properties of grouted macadam, [41]. Understanding the behavior of the asphalt skeleton in comparison to typical open-graded mixes requires analysis of an aggregate structure, as well as the type and amount of asphalt binder. The aggregate structure should be resistant to abrasion, have sufficient tensile strength, and also be porous enough just to allow cement grout to penetrate. According to academic consensus, the asphalt skeleton needs to have at least 25 percent of voids for the grout to flow through, [42]. After grouting, it should be able to preserve residual voids of no more than 5% [43]. The amount of air voids required in porous asphalt for SFP application depends on the type and grade of the aggregate, the asphalt used, and the number of impacts, [44] as shown in Figures 4 and 5.

Figure 3. Porous asphalt paving[45]

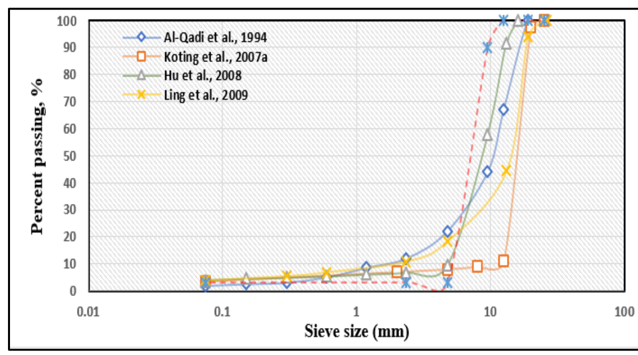

Figure 4. Comparison of different gradations used for PA.

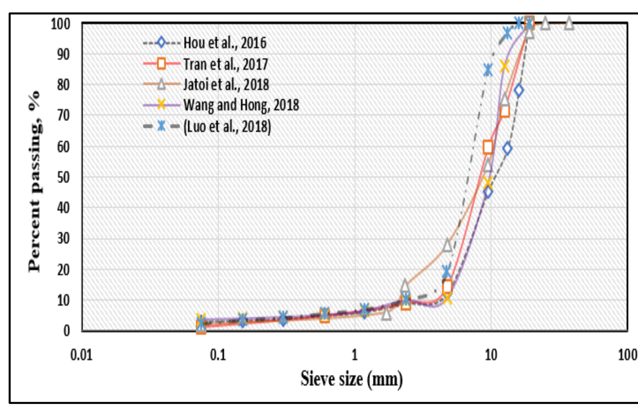

Figure 5. Comparison of different gradations of aggregate used for PA in some previous studies.

5.2 Cementitious grout materials

Cement-based grouts are described as a liquid mixture of additives, water, and cement. The water-to-cement ratio (w/c) is a major factor in cement-based grout [46]. In a semi-flexible layer, the cementitious grout is a crucial component that contributes to stiffness, durability, and high compressive strength. The cementitious grouts must be exceptionally flowable in order to completely permeate the porous asphalt skeleton [47-49] . This has a big impact on how well semi-flexible pavements work. In terms of Marshall stability, stiffness, compressive strength, and resistance to rutting, the modified grouts demonstrated improved results [50].

Cementitious grout materials are frequently manufactured in accordance with the necessity to make a highly flowable substance in the porous asphalt skeleton quickly [51]. In order to endure the effects of tension and pressure, the grout must be made of a high-strength substance. However, other groups are developed for commercial use, although the majority of manufacturers keep their compositions a secret [52].

This section offers accessible cementitious grout material components along with the commonly specified qualities in accordance with the specifications. Table 1 displays numerous grout designs that have been found in various research studies. The studies in the literature claim that the materials used in the grout are the primary variation between the studies. It is noteworthy that the material's surface areas and fluidities have a strong correlation. If cementitious grout materials have a higher surface area, the flow time will be greater, and vice versa. A superplasticizer dependent on polycarboxylic ether polymers is more efficient at the dispersion of cementitious particles than a superplasticizer based on sulfonated naphthalene formaldehyde, and as a result, it provides higher fluidity that can penetrate porous asphalt structure grout [51-53]. Additionally, the fluidity and strength characteristics of cementitious grout materials are significantly influenced by variations in the W/C or W/B ratio. The lowest fluidity value derived by Table 1 is 8.1 seconds [54], where superplasticizers and a high percentage of water were injected, the highest value of fluidity was obtained in [55] research, which took 23 seconds because they used less water. The amount of the utilized grout's fluidity in the SFP injection is determined based on previous research or work done on-site; this is illustrated in Table 2. There are no worldwide specifications that specify this. In order to prevent component separation, Al-Qadi et al. (1994) recommended that the period following grout mixing and flow time determination should not exceed 15 seconds. Although grout preparation in the SFP is dependent on flow time to ensure grout penetration for the porous asphalt and provide the necessary performance characteristics, compressive and flexural strengths are still significant parameters that must be taken into consideration during grout design.

6. Data Collection

Web of Science (WoS) is an online platform that contains many research databases from previous studies and is intended to aid in scientific and academic research. It gives you access to a plethora of databases that refer to research sources for specialized research. This enables users to conduct in-depth searches in specialized subfields of scientific and academic research.

Table 1. Grout components based on previous research.

Authors	Material proportions used in the grout design	Fluidity(sec)
(Al-Qadi et al., 1994)	(38.5 % OPC + 19.2 % Fly ash + 12.7 % Sand + 26.8 % Water) + 2.8 % additive (water-reducing +strength)	8.1
(Anderton, 2000)	(36.6 % OPC + 17.1 % Fly ash + 17.1 % Sand + 25.7 % Water + 3.5 % Resin modifier)	9.0
(Zoorob et al., 2002)	(95 % OPC + 5 % SF + 1 % SP + 0.28 % W/B)	9 – 11
(Hu et al., 2008)	(0.92% OPC + 0.08 Expansion agent type UEA) use as binder + 0.45 W/B + 0.25 S/B + 0.3 SP/B	11.51
(Ling et al., 2009)	(0.65 W/C + 14 % Sand + 10 % Mineral filler powder + 6 % Fly ash)	11.4
(Koting, Karim, Mahmud, Mashaan, et al., 2014)	(95 % OPC + 5 % SF + 0.3 W/C + 2.0 % SP)	15.0
(Al-Taher et al., 2015)	(1:1 OPC and silica sand) + 2 % SP	7-9
(Hou et al., 2016)	(OPC + Water + admixtures), use trial and error	9 – 11
(Jatoi et al., 2018)	(1 OPC: 0.5 Sand: 0.5 Water) by weight + 2 % SP	12.0
(Wang & Hong, 2018)	(0.80 % OPC + 0.05 % SF + 0.15 % Fly ash + 0.29 % W/B) + 8 (ml/kg) SP + 3 (ml/kg) Shrinkage-reducing admixture	23.0
(Luo et al., 2020)	(720 Water + 1000 OPC + 497 Sand + 249 Filler powder+ 30 Latex powder) by gm	12.8

Table 2. Literature-based flow time limitations.

Research	Flow cone type	Grout volume (ml)	Flow Time Range (Sec)
Al-Qadi et al. (1994)	Marsh flow cone	1000	7 – 9
Anderton (2000)	Marsh flow cone	1000	8 – 10
Zoorob et al. (2002)	Flow cone test	1725	9 – 11
Hou et al. (2016)	Flow cone test	1725	11 – 14
Ling et al. (2009)	------	------	10 – 14
Koting, Karim, Mahmud, Mashaan, et al. (2014)	Malaysian mortar flow cone	1000	11 – 16
Husain et al. (2014)	Malaysian mortar flow cone	1000	11 – 16
Al-Taher et al. (2015)	Marsh Flow Cone	1000	8 - 16
Hou et al. (2016)	Leeds flow cone	1000	9 – 11
Jatoi et al. (2018)	Marsh flow one	1000	8 – 12

It has more than 148 million books, journals, and proceedings that date back to the turn of the twentieth century. The three citation indexes that make up the Web of Science are the Science Citation Index Extended, the Social Sciences Citation Index, and the Art, Design, and Humanities Citation Index, [56-58]. A small number of conference proceedings and monographs are also indexed. The Web of Science offers general, cited-referenced advanced search functions as well as a wide variety of tools for modifying search results. All three databases allow for the tracking, counting, processing, and analysis of cited references [59]. WoS is used to search for studies and research on grouted macadam and cementitious grout that relate to the semi-flexible pavement, and the keywords were used in the search (i.e., sustainable grout). Documents for the years 2006–2022 were retrieved from WOS using applicable research criteria and after filtering unrelated research publications. WOS shows some figures that illustrate the relationship between citations and publication numbers. Figure 6 shows that the years 2021 and 2022 have the most publications and citations.

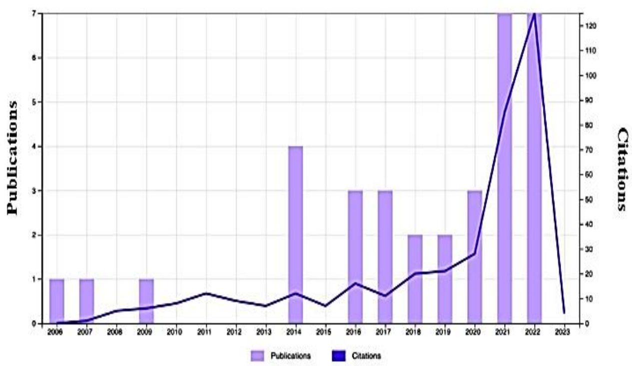

Figure 6. displays the number of scholarly articles produced each year.

7. Analytical Method

Bibliometrics is the study of collections of related documents, such as scientific literature, and it offers well-established techniques for analyzing and depicting connections between research topics, researchers, affiliations, or journals [60]. The bibliometric method can be used with many different programs, such as Bib Excel, Vos Viewer, Pajek, Gephi, CiteSpace, and Histcite. In this study, a VOS viewer was used to create bibliometric and visual maps. This program utilizes a single architecture for both clustering and mapping, which is mostly used for the research of bibliometric networks. VOS viewers can create visualizations in three different categories: overlay visualization, density visualization tools, and network visualizations [61]. Multiple networks, such as the source of articles, publishers, organizations, and countries, can be represented and shown using the VOS viewer as straightforward nodes and links. These networks can be created through citation, bibliographical coupling, co-citation, or co-authorship, [62]. The counting method in VOS viewer is exhaustive, which means that each co-authorship, co-occurrence, bibliographic coupling, or co-citation link is given equal weight. The degree of node connectivity is considered the basic measure of centrality in Cite Space, referring to the node's position within the overall network [63].

8. Top contributions

Table 3 shows the top ten (10) of the most important contributions made by researchers, countries, and universities. The top three terms in the total link strength for authors are Zoorob, Salah, with 47 publications, followed by Khan, Muhammad Imran, with 27 publications, and Rafiq, Waqas, with 25 publications. A high-contributing country with 65 publications is the People's Republic of China, followed by Malaysia with 23 publications and Kuwait with 20 publications. The top three universities in terms of total link strength are the University of Technology Petronas (16 publications), the Kuwait Institute for Scientific Research (15 publications), and the Brno University of Technology (8 publications).

Table 3. The top ten contributions from universities, countries, and researchers.

NO	Authors	Freq	Country	Freq	Institute	Freq
1	Zoorob, Salah	47	People's Republic of China	65	University of Teknologi Petronas	16
2	Khan, Muhammad Imran	46	Malaysia	23	Kuwait Institute for Scientific Research	15
3	Rafiq, Waqas	25	Kuwait	20	Brno Univ Technol	8
4	Sutanto, Muslich Hartadi	25	Pakistan	19	Comsat Univ Islamabad	8
5	Bin Napiah, Madzlan	20	Czech Republic	5	Far Eastern Federal University	8
6	Bokhari, Awais	20	Saudi Arabia	5	King Faisal Univ	8
7	Iqbal, Mudassir	20	England	4	National University of Sciences & Technology	8
8	Khan, Kaffayatullah	20	Portugal	3	Peter the Great St. Petersburg Polytechnic University	8
9	Klemes, Jiri Jaromir	20	Russia	3	Shanghai Jiao Tong Univ	8
10	Ali, Mujahid	20	Italy	2	Engineering & Technology Univ	8

Note: Freq= Frequency, Univ= University.

9. Co-authorship measures

A domain knowledge map of the co-authorship networks of famous writers can give different institutions useful basic pieces to help research teams work together. Additionally, such information can help a lot of researchers looking for new partners and publishers and can create editorial teams using co-authorship data [64].

Figure 7 shows a map of the most prominent authors discussing porous asphalt mixtures and cementitious grouts that affect semi-flexible pavements and their cooperation and shared research. When researchers are in one group or close to another, it indicates the level of cooperation and participation among researchers. The elements are represented and classified by circles of different sizes and colors, and the elements are connected by lines representing the relationships between the elements. The thicker lines represent the strongest communication between the elements, as the space between the items, shows their degree of connectedness. The overall strength of co-authorship connections with other writers is computed. The writers with the most overall links are chosen. As a result, there are 19 items, 4 cluster networks, and 71 links, and the circles are colored based on the clusters. The author's influence increases with the size of the node. The most significant authors include Khan, Muhammad Imran; Zoorob; Salah; Rafiq; Waqas; Sutanto; and Muslich Hartadi, who conducted a variety of studies on grouted macadams. His research with other researchers shows laboratory and field investigation of grouted macadam for semi-flexible pavement [65]. In another study (Application of Sulphoaluminate Cement in Grouted Macadam) as Sustainable Pavement Material, an ideal mixture of the grouting material and porous asphalt skeleton was established, along with a grouting material based mostly on sulphoaluminate cement. According to test results, grouted macadam based on sulphoaluminate cement can achieve compressive strength significantly more quickly than conventional grouted macadam materials [66]. Authors Madzlan Bin Napiah and Salah E. Zoorob Yan have been involved in numerous studies. One of their research types showed a significant relationship between highly flowable cementitious grouts and porous asphalt mixture to construction grouted macadam pavement [45-46]. A network showing the writers' affiliations with each organization and university.

10. Institutes map

In total, there are 12 items in 2 cluster networks and 41 links as shown in Figure 9 as a result of the joint organizations. It is clear that the PETRONAS University of Technology followed by the Kuwait Institute for Scientific Research has contributed more to research on the development of highly flowable cementitious grouts.

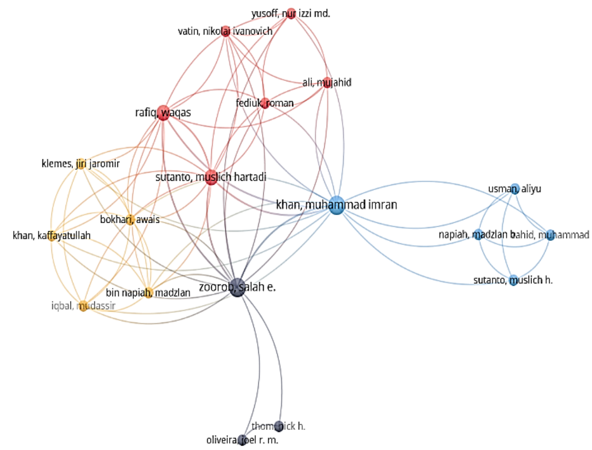

Figure 7. Network visualization map of the author.

11. Country

The network map in Figure 8 depicts the countries that publish the most research related to semi-flexible pavement construction, obtaining 7 items, 2 clusters, and 18 links. The People's Republic of China was first, followed by Malaysia, Kuwait, and Pakistan. These countries have presented a significant amount of research that contributes to the development of sustainable grout that offers enhanced semi-flexible pavement performance.

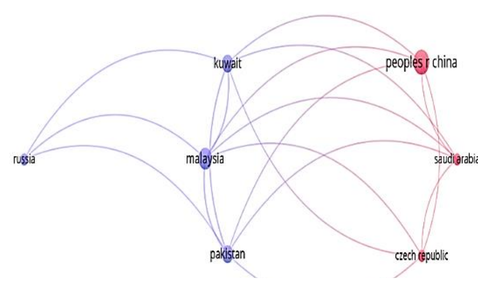

Figure 8. Network visualization map of the countries.

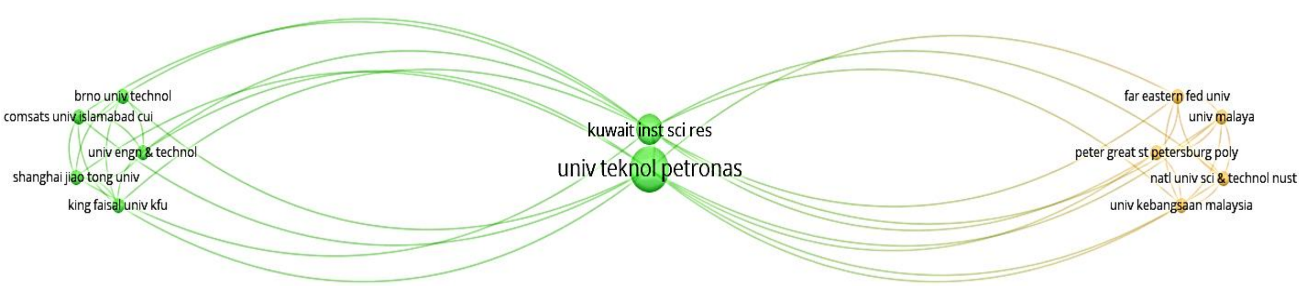

Figure 9. Network showing the writer's affiliation with each organization and university.

12. Co-occurrence measures

12.1. Keywords

One of the most useful methods to show how science subjects and patterns change over time is keyword co-occurrence analysis, which uses short, concise visual maps [60]. The agreed-upon terms disclose the most important aspect of the image: the largest number of people, with each restriction representing one object. According to the Web of Science, the collection of terms for semi-flexible paving contains 62 keywords. The most common keywords used in previous research and studies were grouted macadam, cementitious grout, porous asphalt mixture, mechanical characteristics, grout application, cement slurry, grouting materials, rutting performance, and composite pavement. The joint author keywords, totaling 62 items over 7 cluster networks, are shown in Figure 10. The number of nodes that appear represents the influence of keywords and the extent to which they are used in the web search. These nodes can be used to find the most significant research that links the relationship between cement slurry, performance, asphalt, grouted macadam, and cementitious grout that relate to the design of semi-flexible pavement. The most important word, according to the study, is "semi-flexible" or "Grouted macadam". In addition, compared to other terms, it looked to have the biggest chain and the most links

12.2. Density visualization

The item intensity visualization shows objects based on their labels, just like the link visualization and the combination visualization. The strength of the items is represented by the color at each location in the item intensity visualization. Yellow, green, and blue are the standard color palettes. As the number of items in a point's block grows and as the weights of the obstructing items rise, the point's color tends to resemble yellow more. The reverse is also true: the closer a point's color is to blue, the fewer objects it contains, and the lighter the weights of those that are present. A test serves as an example of item strength visualization. The yellow color in Figure 11 shows the density visualization map of the (co-occurrences). Asphalt mix skeleton, adhesion performance, and grouting are some of the keywords with higher density and close relationships with other terms. Each of these keywords enables the researcher to discover a wide variety of published studies. The most popular keywords are represented by the yellow color, as numerous keywords are used in the same search. Various studies investigating the design of semi-flexible pavement were incorporated [59-64].

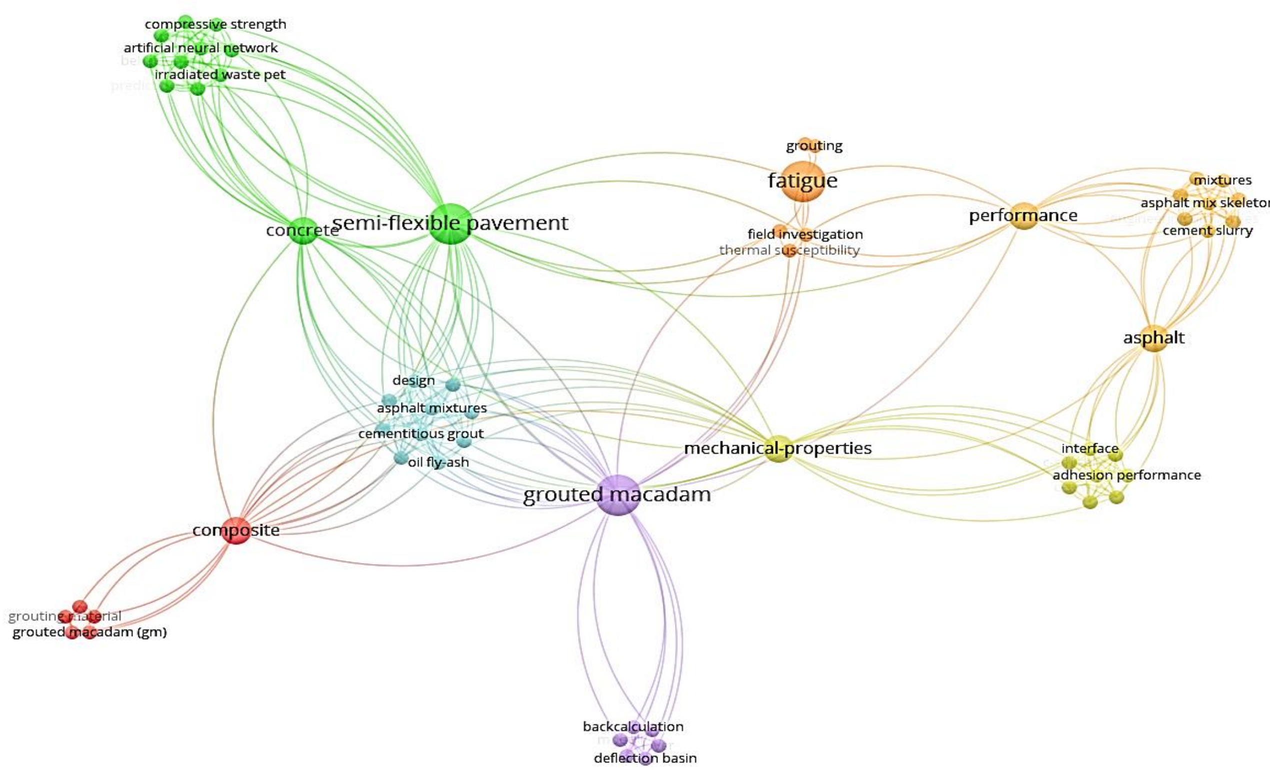

Figure 10. Network visualization map of keywords

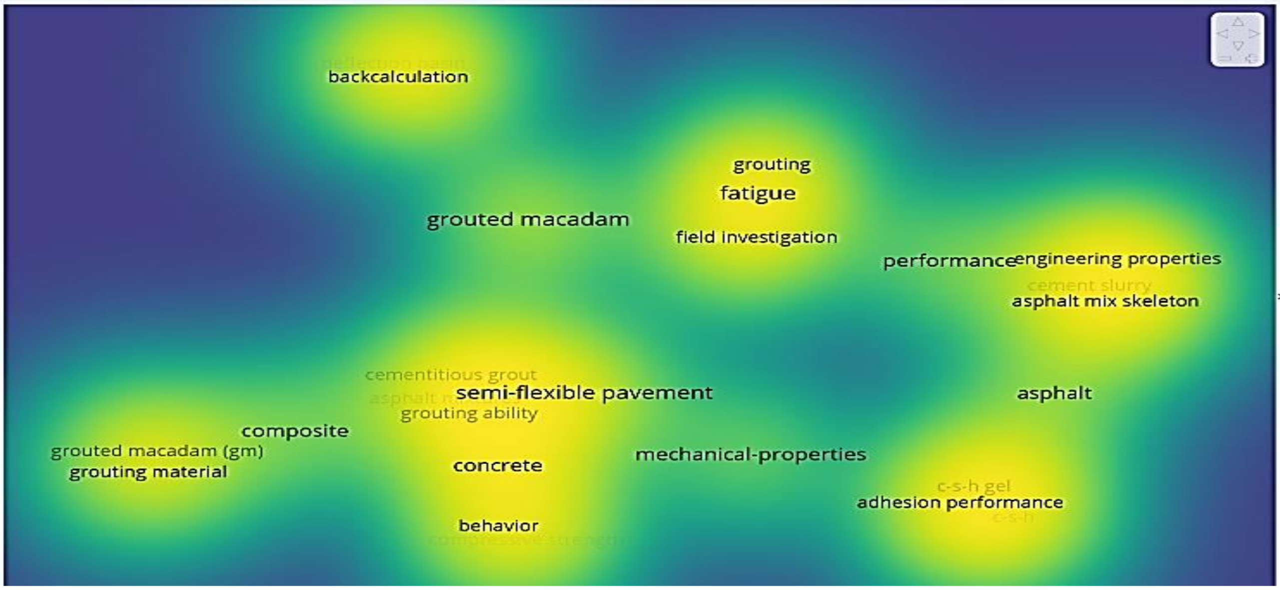

Figure 11. Density visualization map of the keyword

13. Conclusion

The semi-flexible pavement surfaces reviewed in the literature suggest that this kind of pavement layer can create a high-performing pavement surface. The major conclusions from this review are as follows:

- The durability and performance characteristics of semi-flexible pavement surfaces are strongly impacted by the mix design of the porous asphalt mixture and the characteristics of the cementitious grouts. It has been discussed how its choice of bitumen type and gradation of aggregate in porous asphalt mixtures affects the final semi-flexible specimens.
- The behavior of semi-flexible mixes is directly associated with the performances of cementitious grout; the grouts must be very workable to penetrate through the porous asphalt skeleton mixture. In order to produce high-performing semi-flexible paving surfaces, the grouts are precisely designed.
- VOS viewer program was used to identify the most important researchers who have published on grout, their relationship to the semi-flexible pavement, and the extent of their cooperation, including Zoorob, Salah; Khan, Muhammad Imran; Rafiq, Waqas; Sutanto, Muslich Hartadi; Bin Napiah, Madzlan; Bokhari, Awais; Bokhari, Awais; Iqbal, Mudassir; Khan, Kaffayatullah; Klem's, Jiri Jaromir; Ali, Mujahid. Additionally, it determined which countries were most significant in the diffusion of knowledge on this subject, when compared to other countries which are: The People's Republic of China, Malaysia, Kuwait, and Pakistan. Universities that are actively collaborating on research relating to cementitious grout and semi-flexible pavement: the University of Teknologi Petronas, and Kuwait Institute for Scientific Research. As a result, this research offers a road map to help researchers understand the fundamentals of research connected to the relationship between porous asphalt mixture and compendious grout to construct semi-flexible pavement.

Authors' contribution

All authors contributed equally to the preparation of this article.

Declaration of competing interest

The authors declare no conflicts of interest.

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