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A scientometric analysis for construction of sustainable semi-flexible pavements: A review study

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Abstract

The process of construction semi-flexible pavement involves using a combination of a porous asphalt mixture and certain grouting material. This pavement has favourable mechanical characteristics and able to withstand heavy traffic load without premature failure. Grouting materials are crucial in constructing of semi-flexible pavement as they are responsible for filling and reinforcing the asphalt mixture, resulting in gaining high-performance pavement. Prior research has shown its versatility in many applications, including roads, motorways, bridge deck pavement, tunnels, and industrial zones with heavy industrial equipment traffic, airport aprons, and stations. This study aims to identify and collect the most important research papers utilizing the Web of Science (WOS), then analyze the data using the VOS viewer program to identify the importance and extent of researchers' interest in this topic, as well as identify most of the countries and journals that have published about the design, construction, and installation of semi-flexible pavements. As well as the authors and their collaboration, in addition to knowing the keywords that help researchers and authors in researching this topic. It is essential to use these studies to obtain a deeper understanding of the factors that affect the performance of mixtures and semi-flexible mortars, such as material gradation, porous asphalt mixtures, and components of grout materials.

Keywords: Semi-flexible pavement, Grouting materials, Sustainable grout, Porous Asphalt, Grouted Macadam, Cementitious grouts.

Introduction

The impact of increasing population numbers in the world has led to an increase in demand for the use of various types of vehicles, whether transporting people or goods, which has led to an increase in traffic loads on the roads and road deformations and failure. Therefore, pavement must be designed to withstand applied load and severe climatic conditions. There are several types of pavements, including flexible pavements. Flexible pavement consists of several layers based on the natural ground. These layers differ in their properties, where stronger layer is constructed with asphaltic concrete at the top of flexible pavement system. The loads are concentrated on the upper layer and then decrease as they tend towards the lower layers due to the loads being distributed over wide areas [1].The asphaltic concrete is also affected by high temperature leading to premature failure. Viscosity drops at high temperatures, and the adhesion between the particles is diminished, reducing the asphalt's ability to resist shear, compression, and vertical deformation.[2] [3]. The ability of pavement to resist permanent deformation decreases when the temperature of the pavement rises during the summer and when it is exposed to high traffic loads, leading to pavement deformation and material deterioration and an increased risk of traffic accidents [4] [5]. In recent decades, the prevalence of permanent deformations in flexible pavements has significantly increased due to rapid urbanization and a substantial rise in traffic loads, volume, and speed. However, the maintenance cost for highway authorities has increased due to the deterioration of the asphalt binder in asphalt mixes and its susceptibility to extreme temperatures [6]. Although cement concrete pavement is known for its high durability, the prolonged setting time during construction and maintenance may adversely affect the quality and noise levels of the joints, ultimately leading to a subpar driving experience for the driver [7] [8]. Semi-flexible pavement (SFP) is produced by combining porous asphaltic concrete mixture with a greater porosity, usually about 25-35% and cementitious grout material. The SFP outperforms conventional asphalt concrete in terms of mechanical strength at high temperatures making it has better resistance to permeant deformation due to traffic load and temperature such as rutting. When traffic loads are applied to SFP, the material has less vertical deformation and a greater elastic modulus than conventional flexible pavement. In addition, the semi-flexible pavement provides a more comfortable ride than concrete pavement and does not require joints [9] [10]. They are easy to build and maintain, provide a smooth riding experience, and are durable enough [6]. This research aims to provide a clear definition of semi-flexible pavement and how to design and produce it, as well as identify the factors that affect the performance of SFP. This research uses the Web of Science (WOS) to identify the importance of this topic among countries and universities around the world, the most important research publications related to this topic, the extent of researchers' interest in this topic, and the importance of its application to reduce the types of failures to which pavements are exposed. Then, the VOS viewer program was used. To analyze data, including countries and research papers published on the SFP, to obtain more information related to the SFP. These studies can provide sufficient information about the factors affecting the performance of SFP and grout and help identify keywords for valuable academic research.

1. Literature Review

Several research studies have investigated semi-flexible pavements. One was conducted in China on the use of waste materials such as marble and glass in SFP to create an energy-efficient pavement. The results indicated that using 4% marble enhances reflectivity and lighting while reducing energy consumption, providing a more energy-efficient semi-flexible pavement and a superior alternative to traditional asphalt. [11]. Liu et al. conducted research on the bonding properties between PAM and inorganic grout on the mechanical properties of SFP. The study found that the bond strength between asphalt and filler materials significantly affects the low-temperature tensile strength, and compressive strength of SFP. SFP samples immersed in a silane coupling agent solution showed superior tensile strength and shear strength at low temperatures [12]. Ling et al. conducted research on the effect of air voids of a PAM on the shear properties of SFP, applied Mohr-Coulomb theory, and studied the distribution characteristics of pores and cracks. The results displayed that the increasing of air voids can enhance the triaxial compressive strength (it was used to evaluate the shear characteristics of SFP) and modulus of elasticity of SFP, and the main failure mode is the interface crack between cement, asphalt, and aggregate [13]. Liu et al. used solid industrial wastes such as Bayer red clay, coal combustion fly ash, and silica fumes as mineral additives to create a low-carbon green multisolid waste composite filler (ESMSWCGM) for SFP. Based on the results of that study, the three solid mineral waste additives can replace 18% of the cement in ESMSWCGM. The material performs excellently according to compressive strength values at 3h, 1d, 7d, and 28d which were (17.05, 22.95, 29.55, 30.72) MPa, respectively, also the dynamic stability was 28911[14]. Zhao and Yang assessed assessed The efficiency and durability of SFP after modifying cementitious fillers using desulfurization ash (FGD ash), fly ash, and rubber. The efficiency assessment findings and optimization chart of several cement based fillers indicated that the use of FGD ash and fly ash in combination leads to cement-based blended materials that exhibit performance comparable to conventional Portland cement. Using 5% cured rubber powder by weight and a solution containing a concentration of 2% of silane coupling agent (SCA), causes significant enhancement in strength, toughness, size stability, and overall performance of cement-based fillers. The index may be augmented by about 70% or more, while the SFP power can be enhanced by a 30% or more. The production of raw materials significantly impacts the energy consumption and emissions of SFP, particularly cement, which at this stage, energy consumption and emissions are mainly attributed to the factor above, which accounts for 90% or more of the total. Due to the sustained durability of SFP, its energy consumption during its entire life cycle may be decreased by about 30%, leading to a reduction in environmental impact of 30% - 40% [15] Gong et al. used semi-circular bending (SCB) tests to determine how well SFP mixtures were crushed. It used three types of asphalt binders: styrene-butadiene-styrene-modified asphalt binder, MA developed by Sobute New Materials Co. Ltd., and Fiber Compact MA-modified asphalt binder. The findings indicated that including MA and fibers diminishes the potency of the SFP mixture while enhancing the fracture energy and elasticity index—the use of modified asphalt and fiber binder results in improved fatigue performance under high strain ratios. The field checks revealed a reduced number of cracks. [16] . A further study investigated the feasibility of incorporating modified aggregate and reclaimed asphalt pavement (RAP) into cold-mixed asphalt to produce slurry gravel pavements instead of the traditional hot-mixed porous asphalt structure. The study also examined the performance of cementitious plaster when combined with ground glass, Panasquera waste clay, and geopolymer plaster. That work primarily focused on studying the incorporation of mineral waste materials into grouted gravel pavements. The results indicated that the cold composition 8/12.5 with modified granite and cementitious grout containing 30% ground glass shows a superior mechanical performance[2] . Peng et al. examined the feasibility of creating SFP using recycled glass waste as a partial replacement for traditional asphalt pavement components and evaluated its impact on performance. The results indicated that replacing 15% of cement with glass powder or zeolite powder does not affect the mechanical performance while significantly enhancing the reflectivity. SFP, including 40% glass block, has superior high temperature stability, lower surface temperature, lower thermal conductivity, and improved thermal resistance compared to traditional asphalt pavement. The simulation revealed that the SFP, which contained glass, can potentially mitigate the urban heat island effect [17]. Ling, Hu, et al. investigated the impact of several parameters on the bond strength, compressive, modulus of compressive, and strain energy density of SFP casting. The study examined the impact of asphalt type, water-cement ratio, and curing time on the adhesive strength between the cement and asphalt surfaces. The study also examined the extent to which porous asphalt mixture and fillers contribute to the SFP. The findings demonstrated that decreasing the water content in the filler and utilizing highly elastic asphalt can enhance the adhesive strength and mechanical characteristics of SFP. [18]. Hlail,Al-Busaltan and Shaban researchers produced a warm bitumen emulsion, a partially flexible mixture, using locally available materials and energy-efficient heating methods. The mixture's durability was evaluated using sustainable grout: paper ash and silica fume. The results showed an improvement in water sensitivity and aging resistance [19]. Al-Zerejawy and Al-Humeidawi studied the use of ash as a partial substitute for cement and its effect on the mechanical properties of plaster. Reed ash waste, superplasticizer, and water were used. The results showed that increasing water leads to a decrease in flow duration. The optimal replacement rate for reed ash waste was also found to be 10%. [20]. Al-Humeidawi, Chafat, and Kadhim studied using rice husk ash as a partial replacement for cementitious grout and polymer-modified asphalt to create semi-flexible pavements. The study evaluated the mechanical properties of semi-flexible pavement mixtures obtained with and without polymer-modified asphalt. The results indicated that adding polymer-modified asphalt improved Marshall stability by 100% and indirect tensile strength by 50%. It was also found that adding rice husk ash could be an alternative to cement in semi-flexible pavements.[21]. A study evaluated the performance of coal cementitious coal grouting as sustainable grout under different curing temperatures and conditions, focusing on the effects of coal contents (≥30%) and temperatures. Results of mentioned study showed that grout treated at 5, 25, and 35°C had 7.0–7.9%, 5.3-5.4%, and 5.1-6.4% respectively, higher bulk densities than treated at -25°C. Adding coal to low grout increased compressive strength, suggesting that cement and coal were used for grouting at a temperature of 25°C. [22]. The recycling of waste polyethylene terephthalate (PET) through gamma-ray exposure can be used to create cementitious grouts for semi-flexible pavement surfaces. Regular PET and irradiated PET, combined with fly ash and silica fume, significantly increase flow value and compressive strength, providing a sustainable solution for waste PET recycling[23]. Al-Nawasir and Al-Humeidawi studied the mechanical properties of neat asphalt binder when adding styrene butadiene styrene (SBS). The results showed that adding 5% SBS polymer to local asphalt in Iraq reduces bitumen's susceptibility to temperature changes and enhances its characteristics. The polymer-modified bitumen significantly improves rutting and fatigue factors, meeting the requirements of class PG76-10 in central and southern Iraq. This results means last longer life , more comfortable and less maintenance for roads[24].

Based on prior research, it has been observed that the using of SFP offers several benefits compared to flexible and concrete pavement. These advantages include enhanced durability, excellent resistance to corrosion, smooth driving experience for cars, simplified maintenance, and various other merits. Prior research and studies have mostly concentrated on using waste materials to design and construct sustainable building structures, to effectively dispose of trash, minimize construction expenses, and decrease CO2 emissions. Utilizing waste yields satisfying outcomes when employing the ideal ratios of trash. These addition or replacement are calculated based on the tests conducted to evaluate the replacement process. Research have also concentrated on enhancing the characteristics of asphalt by using polymers to increase its effectiveness at high temperatures and heavy traffic conditions.

2. Semi-Flexible Pavement

A SFP is a composite pavement containing features of both concrete pavement and flexible pavement. The first effective use of SFP as airport pavement was in France in 1960. Since that, a lot of research have been carried out on the engineering characteristics and structural design of SFP materials. It consists of a PA mixture with 25–35% air voids. These voids are filled with cementitious grout [25]. Other names for semi-flexible pavements include composite cement-asphalt mixes, grouted macadam, cementitious grout, and asphalt–Portland cement concrete composites. The SFP has notable resistance to shoving corrugation and rutting and is built without the need for contraction, expansion, or building joints. These novel pavement materials have the great strength (hardness) of concrete pavement combined with the flexible qualities of asphalt pavement [26].

3. Application Fields of SFP

The initial semi-flexible pavement creation was implemented in France in the 50s as a surface course safeguard against fuel and oil spills [2]. SFP can be used in any environmental conditions or type of structure of roads such as airport and vehicle pavements, industrial and warehouse floors, fuel depots and commercial gas stations, city plazas and malls, railway stations, and port facilities [27]. SFP is utilized in several airports in the USA and Europe, including number of military airports as well as important commercial airports like Schiphol, Miami, and Copenhagen. In Copenhagen Airport, 165,000 square meters of grouted macadam were built between 1988 and 2000[17]. SFP pouring has gained popularity in nations recently, including China, Japan, Malaysia, Singapore, and India, as well as in Europe like Germany, England, Netherlands and the Italy [28] [29].

4. Grouting Materials Composition

For SFP, the grouting material must be very homogeneous and have minimal dry shrinkage, good adhesion, good fluidity, and appropriate strength. Many components have been added to grouts to accomplish these aims, either producing grouting materials that meet specifications or enhancing specific performance. The high-performance grouting material is especially advised due to its improved moisture susceptibility, low-temperature performance, and high-temperature performance [30] .Compared with traditional cement putty and cement mortar for concrete design, the design of grouting materials for SFPs is different. Grout strength, workability and fluidity are critical factors affecting SFP performance. When the grout is not

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fluid enough, the air space in open-graded asphalt concrete (OAC) asphalt open mixes is not filled, preventing SFPs from exhibiting the necessary strength and durability against applied loads. Grouting materials are designed using different water-cement ratios and additives. In addition, variable cement contents (ordinary Portland cement). When superplasticizers are used and the cement-to-water ratio is maintained, the fluidity of the plaster improves. It is important to emphasize that by adding more superplasticizer the bending strength increases, and the compressive strength increases [31] [32] [33] . Numerous research studies have been conducted to examine the ingredients and dose of grouting materials. These investigations include, but are not limited to, developing high-performance cement grouts using various raw material types and investigating the viability of substituting some fundamental components with alternative materials. A review of pertinent literature has been conducted in order to investigate the general makeup of grouting materials. The outcome is displayed in TABLE 1.

TABLE 1 Typical materials used in grouting materials.

Author	materials used in grouting materials	Additives	Compressive strength (MPa) at 28 day	Flexural strength (Mpa) at28 day	Fluidity (s)
J. Zhang et al. [32]	42.5 OPC + Standard sand+ Mineral powder, fly ash,	-	27	5	11
Davoodi et al.[35]	42.5 OPC + Fine sand + Nano/micro silica + Rubber powder	Superplasticizer + Expansion admixture	36.5	12.4	11
Y. Sun et al.[36]	42.5 OPC + Standard sand + Mineral powder	Superplasticizer + Expansion admixture + Accelerating agent	54.53	7.51	12.7
D. Wang et al. [37]	42.5 OPC + Standard sand + Mineral filler	Latex	22.53	6.5	11.63
Z. Sun et al.[38]	42.5 OPC	Emulsified asphalt, waterborne epoxy + Hardening agent	-	8.26	-

Q. Ding et al.[39]	42.5 OPC + Fine sand	Superplasticizer + Expansion admixture + Viscous agent	-	-	-
W. Wang et al.[40]	42.5 OPC + Natural/ artificial sand + Fly ash, slag powder,	Polymer emulsion + Expansion admixture	69.4	-	-
S. Luo et al.[31]	42.5 OPC + Sand, fines	Latex modifier	24.1	2.81	12.8
K. Zhong et al.[41]	42.5 OPC + Sand + Limestone filler	Latex modifier	23.5	2.8	12.8
B. Fang et al.[42]	32.5 OPC	Superplasticizer + Flexible admixture	32.8	7.2	11
C. Huang et al.[43]	52.5 OPC + Fine sand + Mineral admixtures	Superplasticizer + Emulsified asphalt + Expansion admixture	48.6	7.41	11.5
S. Koting et al.[44]	OPC, White Cement + Silica fume	Superplasticizer	92.5	-	15
S. Zarei et al.[45]	Cement	Superplasticizer + Asphalt emulsion + Defoamer, viscosity modifying agent	-	-	-
M. Khan, et al.[46]	Portland Cement type I + Fly ash, silica fume + PET	Superplasticizer	55	7.6	12.6
Hamzani, et al.,[23]	Portland Cement type II + Fine sand + Zeolite + Waste tire rubber	-	60	-	15
M. Afonso	Portland cement	Superplastici	-	-	13

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et al.[2]	CEM I 42.5R + Milled glass, waste mud	zer + Alkali-activator			
Y. Fang et al.[47]	OPC, SAC + Silica fume	Superplasticizer	60	-	15
J. Ren et al. [48]	42.5R OPC	Superplasticizer + Expansion admixture + Accelerating agent	35	10.68	10.6
X. Chen et al.[49]	SAC + Fly ash, silica fume	Superplasticizer	56	-	15
C. Huang et al.[50]	SAC + Fine sand + Mineral admixtures + Waste rubber powder	Superplasticizer + Expansion admixture	48.6	-	-
B. Lee et al. [51]	R cement	Acrylate(resin), + Expansion admixture	55	-	14
H. Deng e al. [52]	R cement + Carbon black + Carbon black	Superplasticizer + Defoamer	42.5	7.5	-
S. Zhang et al.[53]	Fine sand + Slag	Alkali activator	38.8-62.35	3.4	14
Y. Zhang et al.[54]	Geopolymer	-	37.5	-	13
A. Huynh et al.[55]	Geopolymer	-	108	-	11
(Al-Nawasir and Al-Humeidawi,) [56]	Cement+ ceramic waste powder (CWP)	superplasticizer	59	13.5	13

NOTE: SAC is for Sulphoaluminate cement, OPC stands for Ordinary Portland cement, SBR stands for styrene butadiene rubber, and R cement refers to a type: A rapid hardening cement.

FIGURE1. illustrates that there are two steps involved in constructing semi-flexible pavements (SFPs). Initially, the paving mixture is created with an air void content of 20% to 35%. During the second step, grouts, such as cementitious grout or cement paste, are introduced into the

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asphalt mixes. The properties of the grout and the thickness of the asphalt mixture then determine how long the mixture must cure [10].

Figure 1. A Depiction Of The Blending Process For Semi-Flexible Pavements [10].

5. Data Collection

The main goal of the Web of Science (WOS) web platform is to facilitate scientific and academic research activities by providing a plethora of research datasets, including historical studies. This platform provides users with extensive access to many databases, including research materials relevant to specialized areas of study. This feature enables users to search comprehensively within certain scientific and scholarly study sub-disciplines. The collection encompasses many literary works, periodicals, and instructional materials, totalling over 148 million items from the early 1900s [57]. The Web of Science comprises three citation indexes: Expanded Science Citation Index, the Social Sciences Citation Index, and the Arts, Design, and Humanities Citation Index. A limited quantity of conference proceedings and papers are also included in the index. The Web of Science provides users with extensive search options for both general and referential searches, along with a diverse set of tools to change and refine search results. All three databases monitor, quantify, manipulate, and examine referenced references. A domain knowledge map of well-known authors' co-authorship networks may provide various institutions with helpful foundational information to support collaborative research teams. Many academics searching for new collaborators and publications might benefit from this information since it can be used to construct editorial teams based on co-authorship data. Numerous studies have extensively used Web of Science (WOS) and VOS viewer software, particularly in semi-flexible pavement [58] [59] [60]. Numerous scholarly investigations have examined the

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utilization of waste materials in semi-flexible pavement and comprehensively examined scientific measuring methodologies.

6. Analytical Method

Bibliometrics offers a dynamic, evaluative, and predictive approach to scientometric analysis. The concept in question originates in the area of library and information science. However, it has gained widespread acceptance and integration in several other disciplines, particularly for the purpose of conducting quantitative studies by researchers, institutions, and academic publications focused on scholarly outputs. Several computer tools and packages have been developed for the purpose of doing bibliometric analysis. Examples of these programmes are Bib Excel, Cite Space, Pajek, Gephi, Vos Viewer, and Histcite. In current research, VOSviewer was used in the creation of visualisations and bibliometric maps. The programme employs a cohesive architecture for the purpose of mapping and clustering, with its primary application being the study of bibliometric networks. Capability to generate three distinct forms of visual representations, namely density visualisations, overlay visualisations, and network visualisations. Many researchers used the VOS viewer program to create charts and graphs showing the most prominent researchers, journals, and countries interested in the subject of research and development of sustainable pavement and to create a scientific overview [61,63].

6.1. TOP Contributions

Table 2 shows the ten contributions by authors, countries, and institutes. Regarding total link strength, the top three authors are Defelice, Gianmarco, with 75 publications; Desantis, Stefano, with 71 publications; and Khan, Muhammad Imran, with 59 publications. A highly contributing country with 51 publications is People's Republic of China, followed by USA with 43 publications and England with 32 publications. The top three terms of the total link strength for universities are Southeast University with 43 publications, University Bologna with 43 publications, and Roma Tre University with 42 publications.

TABLE 2 Top 10 contributions of institutes, countries, and authors.

No	Authors	Freq	Institute	Freq	Country	Freq
01	Defelice,gianmarco	75	Southeast U.	43	Peoples r china	51
02	Desantis , stefano	71	U.Bologna	43	USA	43
03	Khan ,Muhammad imran	59	Roma tre U.	42	England	32
04	Ceroni , Francesca	52	U.Naples federicoii	41	Italy	32
05	Lignola , gian piero	49	Politecn milan	35	Malaysia	28

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06	Hong , jinxiang	48	State key lab high performance civil engnmat	35	Pakistan	27
07	Peng , gang	47	U. naples parthenope	33	Saudi arabio	26
08	Mazzotti , Claudio	45	U. teknol petronas	31	Australia	24
09	Gong , minghui	44	U. minho	26	France	17
10	Poggi , carlo	44	U. padua	23	Canada	17

Note: F= Frequency, U= University

6.1.1.CO-Authorship Measures

A domain knowledge map of well-known authors' co-authorship networks may provide various institutions with helpful foundational information to support collaborative research teams. A lot of academics searching for new collaborators and publications might benefit from this information since it can be used to construct editorial teams based on co-authorship data... Fig. 2 displays a map illustrating the leading authors who have contributed to the discussion on porous asphalt mixes and cementitious grouts, which has an impact on semi-flexible pavements. The map also highlights their collaboration and joint research. The proximity of researchers to one another or to a specific group is indicative of the degree of collaboration and engagement among researchers. The components are shown and categorized using circles of varying dimensions and hues, while the connections between the elements are illustrated by lines denoting their interactions. The thicker lines indicate the most robust connection between the pieces, while the spacing between the items reflects their level of interconnectedness. The collective robustness of co-authorship ties with other writers is calculated. The authors that have the highest number of total connections are selected. Consequently, there are a total of 62 items, 8 cluster networks, and 576 linkages. The circles are colored according to the clusters. The author's impact grows proportionally with the magnitude of the node. The notable writers include Defelice, Gianmarco; Desantis, Stefano; and Khan, Muhammad Imran.

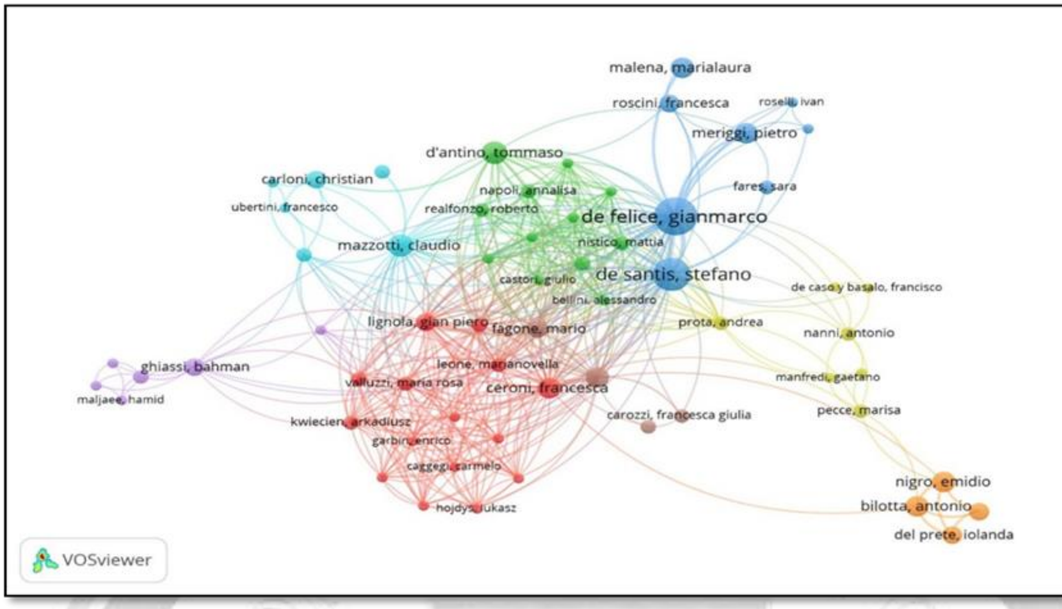

FIGURE 2. Author's network visualisation map

6.1.2.Institutes map

FIGURE 3. shows the joint organizations resulting in a total of 270 items in 24 cluster networks. It can be noticed that Southeast University, University Bologna, Roma Tre University, University Naples Federico, and Politecn Milan have the highest contribution to work related to semi-flexible pavements.

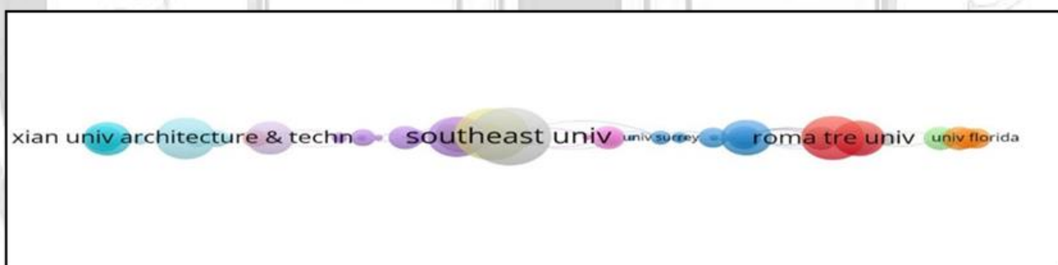

FIGURE 3. Network visualization map of the Institute

6.1.3.Country map

The network map shown in Fig. 4 show cases the nations that publish the most amount of research pertaining to semi-flexible pavement construction, yielding a total of 54 publications. The map further reveals the presence of 11 distinct clusters and a total of 274 connections between the publications. China was the first country to establish the People's Republic, followed by the United States, England, and Italy. These nations have offered a substantial body of

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research that contributes to the advancement of sustainable grout, which provides improved performance for semi-flexible pavement.

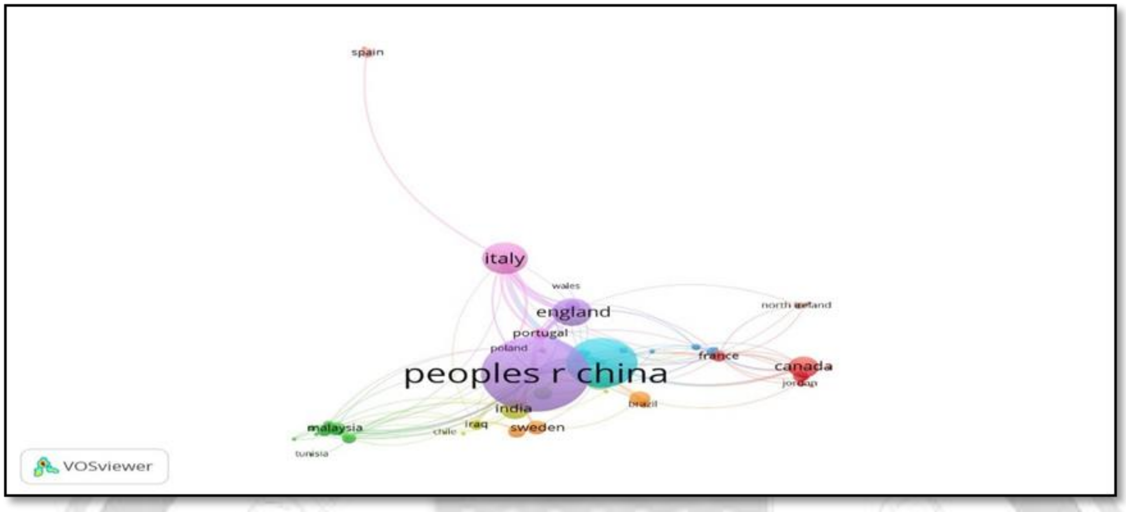

Figure 4. displays a network visualisation map of the Country.

7. CO-Occurrence Measures

Figure 5 displays the terms the author has in common with others, resulting in 1000 items distributed throughout 27 cluster networks. Multiple nodes are shown, each displaying its own colour and size to indicate the level of impact of keywords and the frequency of their use in the search engine. It have been identified several keywords that may be used to locate the most significant studies contributing to the advancement of semi-flexible. The yellow hue in Figure 6 is a density visualisation map illustrating the events that happen simultaneously. The prominent nodes indicate the most often used keywords, while the line reflects the level of proximity between these phrases since several keywords are associated with a single search.

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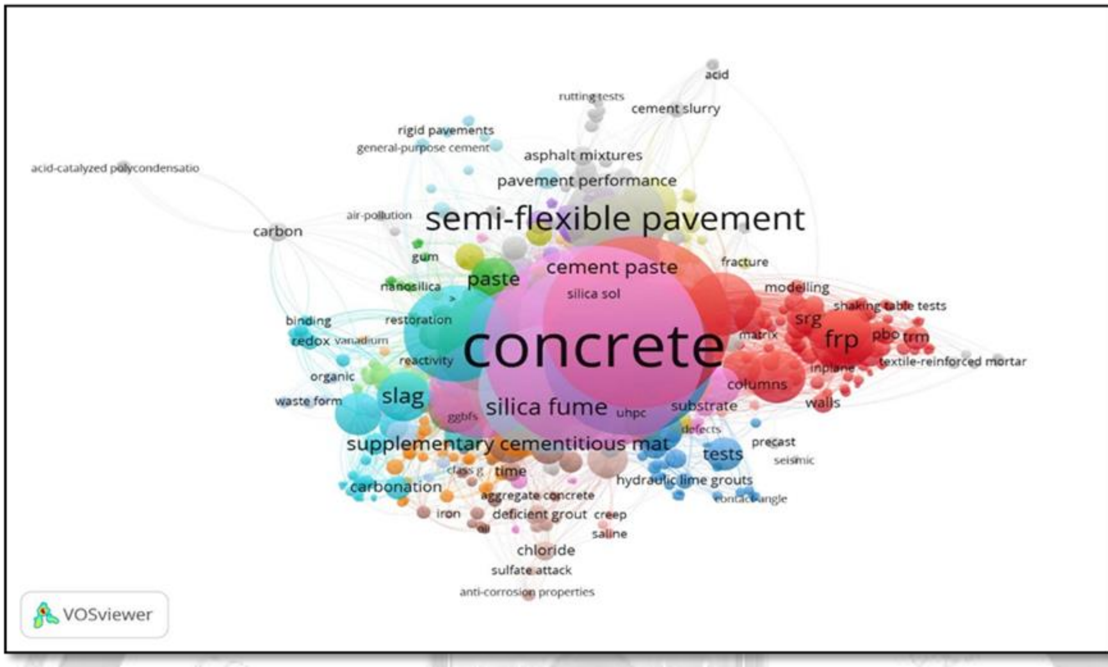

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Figure 5. Graphical representation of keywords in a network visualisation map

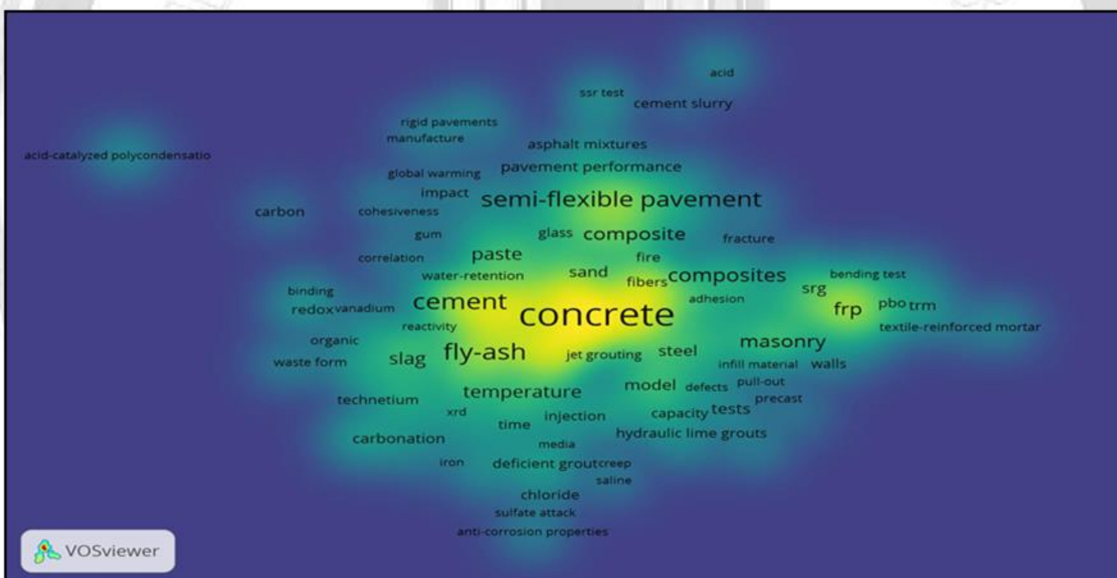

Figure 6. Density visualization map of keywords

8. Conclusion

Several research has conducted to produced SFP can get the advantages of both flexible and rigid pavements also to overcome the limitation of these types of pavement. Some of these studies aim to investigated an alternative or sustainable materials to reduce demand on natural resource and protect the environment. The major findings derived from this review may be summarized as follows**:**

1. The grouting material is a crucial component of SFP, substantially impacting its performance**.**
2. An optimal grouting material should possess the following characteristics: excellent flowability, adequate strength, little dry shrinkage, high consistency, and strong adhesion. Fluidity, dry shrinkage, and strength come in that order as the three most important characteristics**.**
3. The longevity and performance SFP are greatly affected by the composition of the porous asphalt mixture and cementitious grouts used in their construction. The selection of bitumen type and aggregate gradation has a significant impact on the quality of the semi-flexible specimens**.**
4. The VOS viewer software was utilized to ascertain the primary researchers who have published on grout, their association with the semi-flexible pavement, and the level of their collaboration. These researchers include Defelice, Gianmarco; Desantis, Stefano; Khan, Muhammad Imran; Ceroni, Francesca; Lignola, Gian Piero; Hong, Jinxing; and Peng, Gang**.**Mazzotti, Claudio; Gong, Ming Hui; Poggi, Carlo. Furthermore, it identified the nations that had a prominent role in disseminating information on this topic compared to other countries. These countries include China, United States, England, Italy, Malaysia, Pakistan, Saudi Arabia, Australia, France, and Canada **.**
5. The universities actively engaged in collaborative research on cementitious grout and semi-flexible pavement include Southeast University, University of Bologna, and Roma Tre University. This research provides a comprehensive guide for scholars to grasp the essential aspects of studying the connection between porous asphalt mixture and compacted grout in constructing semi-flexible pavement**.**
6. More studies are required to investigate sustainable materials to replace the conventional grouting materials and reduce the demand on natural resources and reduce the harmful effect on environment by recycling these materials in roads construction.

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التحليل العلمي لبناء الأرصفة شبه المرنة المستدامة: دراسة مراجعة

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الخلاصة

تتضمن عملية بناء الرصيف شبه المرن استخدام مزيج من خليط الأسفلت المسامي وبعض مواد الحشو. يتمتع هذا الرصيف بخصائص ميكانيكية مناسبة وقادر على تحمل الأحمال المرورية العالية دون حدوث فشل مبكر. تعتبر مواد الحشو حاسمة في إنشاء الرصيف شبه المرن لأنها مسؤولة عن ملء وتعزيز الخليط الإسفلتي، مما يؤدي إلى الحصول على رصيف عالي الأداء. وقد أظهرت الأبحاث السابقة تنوعها في العديد من التطبيقات، بما في ذلك الطرق والطرق السريعة وأرصفة سطح الجسور والأنفاق والمناطق الصناعية مع حركة المعدات الصناعية الثقيلة وساحات المطارات والمحطات. تهدف هذه الدراسة إلى تحديد وجمع أهم الأوراق البحثية باستخدام شبكة العلوم (WOS)، ثم تحليل البيانات باستخدام برنامج VOS viewer للتعرف على أهمية ومدى اهتمام الباحثين بهذا الموضوع، وكذلك التعرف على معظم الأوراق البحثية و الدول والمجلات التي نشرت عن تصميم وبناء وتركيب الأرصفة شبه المرنة. وكذلك المؤلفين وتعاونهم، بالإضافة إلى معرفة الكلمات المفتاحية التي تساعد الباحثين والمؤلفين في البحث في هذا الموضوع. ومن الضروري استخدام هذه الدراسات للحصول على فهم أعمق للعوامل التي تؤثر على أداء المخاليط والملاط شبه المرنة، مثل تدرج المواد، والمخاليط الإسفلتية المسامية، ومكونات مواد الجص.

الكلمات الدالة: الرصف شبه المرن، مواد الحشو، الجص المستدام، الأسفلت المسامي، الحصباء الملاطة، الجص الإسمنتي.