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Exploring the Underlying Constraints to the Use of Geosynthetics for Civil Engineering Infrastructure: A Study from Ghana

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Whereas the level of use of geosynthetics on continental basis is generally considered to be low, little is known of country-specific studies that unravel the constraints to the use of geosynthetics for civil engineering infrastructure in the construction industry. Thus, this study seeks to identify the underlying constraints to the use of geosynthetics for civil engineering infrastructure in Ghana and determine the relative significance of each of the underlying constraints on the use of geosynthetics for civil engineering infrastructure in Ghana. A mixed methodology was employed. A structured questionnaire and structured interview helped in data collection. Data were analysed using frequencies, percentages, mean, standard deviation, one sample t-test, and the Relative Significance Index (RSI). Nineteen (19) underlying constraints were identified as the constraints to the use of geosynthetics in Ghana. Each recorded a significant RSI value from 0.70 to 0.95 and t-test values were statistically significant. The lack of a geosynthetic research institute to champion research-driven campaigns for geosynthetics use in Ghana, and the use of geosynthetics is not prioritized in the manifestos of political parties in Ghana were unique constraints to this Ghana study only. In terms of civil and construction engineering practices, this study has offered an understanding of the constraints to the use of geosynthetics in Ghana and provided the theoretical basis for future geosynthetic-related studies.

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1. INTRODUCTION

The traditional way of design, construction, and maintenance of civil engineering infrastructure such as roads, railways, buildings, dams, breakwaters, and landfill sites, among others, has negatively impacted the environment; resulting in, among others, depleted natural reserves such as soils and rocks within the environment [1]. This is usually the case when the soil is weak and needs to be improved for civil engineering infrastructure [2]. The traditional practice for improving weak soil conditions was limited to replacing unsuitable soils or bypassing them with costly deep foundations [1]. However, the emergence and use of geosynthetics as an integral part of civil engineering infrastructure have proven to be an environmentally friendly and more sustainable approach to improving the conditions of soils and rocks for civil engineering infrastructure [1,3]. Geosynthetics are polymeric materials used to enhance, improve or stabilize a soil, rock, earth, or any geotechnical substance, as an integral part of civil engineering infrastructure [4,5]. Geosynthetics come in the form of strips, sheets, or three-dimensional structures [4,5]. Geosynthetics have given alternative use to polymers [4]. Thereby contributing to the realization of the sustainable development goals by 2030. Specifically goal 12: Responsible Consumption and Production, which among others encourages companies, especially large and transnational companies, to adopt sustainable practices in the procurement of civil engineering infrastructure, reducing waste generation substantially through prevention, reduction, recycling, and reuse [6].

According to the American Society for Testing and Materials (ASTM), Committee D35 on geosynthetics, geosynthetics are planar products produced from polymeric materials and used with rock, soil, earth, or other geotechnical engineering-related material as an integral part of a man-made structure, project, or system [7]. Thus, geosynthetics define a variety of polymeric materials used as an integral part of civil engineering infrastructure. Geosynthetics encapsulate nine major categories of products: geotextiles, geonets, geogrids, geomembranes, geosynthetic clay, geofoam, geopipes, geocomposites, and geocells [5,8]. The primary functions of geosynthetics include filtration, separation, drainage, reinforcement, environmental protection, and provision of a fluid barrier [4,9]. The root of the use of geosynthetics could be traced to the days of the Pharaohs in ancient Egypt when it was used for road works [10]. However, notwithstanding the comparative advantage the use of geosynthetics offers when compared with traditional alternatives; coupled with the wider acceptance and successes the use of geosynthetics has brought, with India recording a daily increase in the use of geosynthetics [11]; available global statistics show that the use of geosynthetics for civil engineering infrastructure in Africa only explains 7 per cent of global use of geosynthetics whereas Europe, North America, and Asia account for 30, 34 and 25 per cent respectively [4]. The percentages of the level of use of geosynthetics on a continental basis suggest a generally low level of use on a continental basis with Africa being worse off. Therefore, whereas the level of use of geosynthetics on a continental basis is generally low, little is known of country-specific studies that unravel the constraints to the use of geosynthetics for civil engineering infrastructure. Thus, the relevance of this current study lies in the fact that it seeks to identify the underlying constraints to the use of geosynthetics for civil engineering infrastructure in Ghana and determine the relative significance of each of the underlying constraints on the use of geosynthetics for civil engineering infrastructure in Ghana.

The specific objectives that governed the study were:

- to identify the underlying constraints to the use of geosynthetics for civil engineering infrastructure in Ghana,
- to determine the relative significance of each of the underlying constraints on the use of geosynthetics for civil engineering infrastructure in Ghana.

Though this is a Ghana study and does not seek to generalize its findings to represent that of Africa or the globe due to the dynamics and the composition of the construction industry across the globe. However, it offers lessons for countries, such as Nigeria, Burkina Faso, Angola, Malaysia, and South Africa whose construction industry shares some close resemblances with that of Ghana. Moreso, geosynthetic-related studies in existence largely adopted the case study approach to research, focusing on either industry or the nation at large (see [1,11,12]). This is due to the strength of the case study research design to aid in unravelling in-depth findings, among others (see [11]). Riding at the back of the strengths of a case study research design, this current study adopted a case study research design, and the case study area was Ghana. Ghana like other developing countries requires sustainable construction technologies to meet its infrastructure deficits without any adverse effect on the environment but apparently, there is a lack of literature on the underlying constraints to the use of geosynthetics for civil engineering infrastructure in Ghana as well as the level of use of geosynthetics for civil engineering infrastructure in Ghana. Whereas this current study addresses the underlying constraints to the use of geosynthetics for civil engineering infrastructure in Ghana, the study recommends a future study that addresses the level of use of geosynthetics for civil engineering infrastructure in Ghana.

Moreso, Ghana was chosen for the study because Ghana's construction industry shares close characteristics with that of many developing countries and it is believed that Ghana's findings will offer fruitful lessons for other developing countries.

Previous studies inform that geosynthetics have been used for civil engineering infrastructure such as roads, railways, harbours, and landfills, among others [5,8,11]. Civil engineering infrastructure is the collective name for the basic systems and facilities that help society to function and maintain the environment [13]. They include roads, railways, buildings, tunnels, canals, dams, ponds, manholes, pipes, earth retaining structures, wastewater treatment systems, landfills, water supply systems, breakwaters, airfields, and utilities, among others [13].

2. CONSTRAINTS TO THE USE OF GEOSYNTHETICS

Few studies have advanced some constraints to the use of geosynthetics. For instance, in a study in Lagos, Nigeria, the effect of weather, user's choice, cost of labour, cost of geosynthetic materials, the capacity of contractor, transportation, life cycle cost, economic status, low level of knowledge among civil engineering practitioners, low level of knowledge among civil engineering graduating students, and proximity to the site [11] were identified to be constraints to the use of geosynthetics. However, constraints such as transportation, life cycle cost, cost of geosynthetic materials, and labour cost have been debunked by [14] and [15]. The two authors argued that the use of geosynthetics offers a comparative cost advantage instead. The cost advantage in the use of geosynthetics encapsulates but is not exhaustive, cost savings in extra material, reduction in the amount of waste material, and reduction in the cost of transportation. Thus, cost advantage is project-specific [14,15]. Given this, this study will rather consider the perceived high cost of geosynthetics as a constraint to the use of geosynthetics in addition to other constraints to the use of geosynthetics. According to [16], global and national status of geosynthetics awareness regarding graduating civil engineers, as well as new employees entering into geosynthetics design and consulting organizations, are presently not only weak but also show no promise of improving. GSI [16] further informed that all graduating members of civil engineering and all new employees have little knowledge of the plethora of available geosynthetics including the various applications or uses they serve. As a result, negatively impacting on the use of geosynthetics. In addition, the high cost of setting up geosynthetic laboratories in training students, and the lack of geosynthetic laboratories to support testing, have been major constraints to the use of geosynthetics [16]. USEPA [17] identified factors such as inadequate design and installation standards, inadequate construction and installation standards, and inadequate research to promote the use of geosynthetics to be constraints to the use of geosynthetics. Zornberg [18] identified ingenuity in the use of geosynthetics as a constraint to the use of geosynthetics. Raja [14] opined that inadequate education, cost of geosynthetic products, the perception that geosynthetics are a new technology that is not tried and tested compared with the traditional methods which are tried and tested, lack of technical know-how in design using geosynthetic technology, inadequate funding for research, lack of awareness among clients on geosynthetic-based solutions to their civil engineering needs, fear of using an imitated product, client's lack of experience in working with geosynthetics, conservative approach of consultants, and cost of the product were the constraints to the use of geosynthetics. Raja [14] further explained that the lack of education on the use of geosynthetics in the construction industry, among engineers, designers and contractors is a constraint to the use of geosynthetics for civil engineering infrastructure.

Specifically, in the UK, [14] attributed the lack of education to insufficient education on the use of geosynthetics in degree courses. This affirms the revelation that there is a low level of awareness of geosynthetics among civil engineering students [16]. Ministry of Textile [12] informed that inadequate policies to promote the use of geosynthetics, low awareness of the economic benefits one derives from using geosynthetics, and lack of schedule rates for pricing seriously constrain the use of geosynthetics [12].

Thus, whereas some disparities in views exist among authors concerning the constraints to the use of geosynthetics, there exists some level of consensus in the views of the authors also. However, the constraints are context or country-specific and therefore, do not represent what is prevailing in Ghana. Therefore, the need to undertake an empirical study to identify the underlying constraints to the use of geosynthetics for civil engineering infrastructure in Ghana and determine the relative significance of each of the underlying constraints on the use of geosynthetics for civil engineering infrastructure in Ghana. Consequently, informed by the literature reviewed and consensus in view among authors in previous studies, the following constraints guided the Ghana study: low level of knowledge among construction practitioners on the use of geosynthetics, low level of knowledge among construction and civil engineering graduating students on geosynthetics, inadequate policies to promote the use of geosynthetics, low awareness of the economic benefits one derives from using geosynthetics, lack of schedule rates for pricing geosynthetics, insufficient curriculum provisions on geosynthetics in construction and civil engineering disciplines, lack of awareness among clients on geosynthetic-based solutions to their civil engineering needs, the conservative approach of consultants, fear of using imitated geosynthetics, perceived high cost of geosynthetics, the perception that geosynthetics are a new technology which is not tried and tested, inadequate design and installation standards regulating the use of geosynthetics in the construction industry, lack of technical know-how in design using geosynthetic technology, client's lack of experience in working with geosynthetics, lack of education on the use of geosynthetics, contractors do not have the capacity to use geosynthetics, inadequate geosynthetic laboratories to support testing of geosynthetics.

3. METHODOLOGY

This study employed a mixed methodology. A three-stage approach to research was adopted.

Firstly, the literature was reviewed which aided in identifying the underlying constraints to the use of geosynthetics for civil engineering infrastructure. The second stage was the use of the structured interview to purposively seek the views of 10 key stakeholders in the Ghanaian construction industry about the underlying constraints to the use of geosynthetics for civil engineering infrastructure. This aided in conceptualizing the underlying constraints to the use of geosynthetics in Ghana. The stakeholders were chosen based on their rich knowledge and/or experience on the issue being investigated for over two decades. The stakeholders comprised two (2) academics in civil engineering (one (1) from a public university and one (1) from a private university), and two (2) lead members each from professional and association affiliates in the Ghanaian construction industry. The professional and association affiliates were the Institution of Engineering and Technology (IET), Ghana, the Ghana Institution of Surveyors (GhIS), the Ghana Institute of Architects (GIA), and the

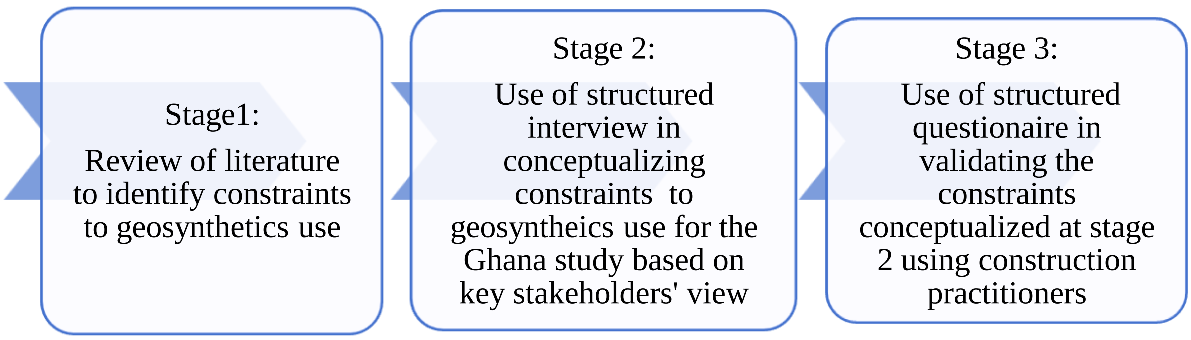

Fig. 1. Flow chart for the research processes

Association of Building and Civil Engineering Contractors of Ghana (ABCECG). The key stakeholders were asked to rate the underlying constraints to the use of geosynthetics for civil engineering infrastructure in Ghana using a 5-point scale, where (1) represents a highly insignificant constraint, (2) is an insignificant constraint, (3) is neutral, (4) is a significant constraint, and (5) denotes highly significant constraint. Blank spaces were provided for the respondents to further suggest constraints that were not captured in the structured interview.

In line with research ethics, the names of the respondents were kept confidential. Table 1 presents the outcome of the enquiry based on the views of the key stakeholders. A structured interview was the instrument used in the data collection. Data were analysed using the standard deviation and the mean. Data were further analysed using one sample t-test. This helped in comparing the mean value of the underlying constraints to the use of geosynthetics for civil engineering infrastructure to the population/hypothesized mean to check the level of statistical significance of the identified underlying constraints. Accordingly, a hypothesized mean was set at 3.5 (see [19]). The significance level was also set at 95% following predictable risk levels (see [19]). Underlying constraints with a significant (1-tailed) value not exceeding 0.05 were considered statistically significant and were included for subsequent validation (see [19]). Thus, nineteen (19) constraints were found to be statistically significant, hence were conceptualized to be the underlying constraints to the use of geosynthetics for civil engineering infrastructure in Ghana.

The third stage was the use of a structured questionnaire in validating the identified constraints conceptualized based on the views of the ten (10) key stakeholders in the construction industry in Ghana. The respondents included construction practitioners from 257 construction firms who belonged to ABCECG. This sample size of construction firms was determined based on the principle by Neuman [20] that, for a population of size around 1500, 20% should be sampled (see [20,21]). Thus, 20% of the population of 1282 construction firms registered with ABCECG was equivalent to 257 construction firms. The population size was obtained from the ABCECG secretariate as affirmed by [22]. ABCECG was chosen as the study population because it was the association for building and civil engineering contractors (construction firms) in Ghana with members in all the regions of Ghana. In each firm, information was solicited from construction practitioners within the field of civil engineering, construction engineering, construction technology, or building technology who had used geosynthetics for civil engineering infrastructure for at least five (5) years. This aided in ensuring that the respondents had experience and knowledge regarding the issue under investigation and that the quality of responses could be vouched for. In addition, the views of 5 consultants in the field of environmental engineering, road engineering, civil engineering, construction management, and quantity surveying who have worked on a project that used geosynthetics were purposively included. Thus, the views of 262 construction practitioners were sought on the underlying constraints to the use of geosynthetics for civil engineering infrastructure in Ghana.

In this study, construction practitioners include consultants and workers within construction firms in the field of civil engineering, construction engineering, construction technology, and building technology. Thus, construction practitioners were asked to rate the 19 underlying constraints to the use of geosynthetics for civil engineering infrastructure in Ghana using a 5-point scale, where (1) represents highly insignificant, (2) is insignificant, (3) is neutral, (4) is significant, and (5) denotes highly significant based on their experience and/or knowledge. Experience means work experience relating to geosynthetics or having worked in the construction industry for at least five years. Knowledge means having formal or informal information on geosynthetics for civil engineering infrastructure.

According to Creswell [23], two fundamental objectives govern the design of a questionnaire: to maximize the response rate and, to obtain accurate relevant information for and from a survey. A 100% response rate was recorded because the questionnaire was self-administered with the help of twenty (20) field workers from March 2022 to July 2022. Respondents spent at most 8 minutes on the survey, and further clarification was provided when requested. Informed by the assertion that the way a questionnaire is worded has an enormous influence on the nature of information elicited [23], the questionnaire for this current study was carefully worded using clear and simple sentences. Data were analysed using the

Relative Significance Index (RSI) using the formula:

$$RSI=(\sum W)/(A*N)$$

where, W—weight that is given to the statement by the research respondents. It ranged from 1 – 5 in this study. A in the formula represents the highest integer and, in this study, (5). N is the total number of research respondents [24,25]. The RSI scores range from 0.00 to 1.00 (see [24]). The closer the score to 1.00 the more significant the variable or factor.

4. RESULTS AND DISCUSSION

According to Table 1, nineteen (19) underlying constraints to the use of geosynthetics for civil engineering infrastructure were identified. Among the 19 constraints, it was observed that seventeen (17) were consistent with the literature findings of previous studies, whilst two (2) constraints namely, lack of a geosynthetic research institute to champion research-driven campaigns for geosynthetic use in Ghana, and the use of geosynthetics is not prioritized in the manifestos of political parties in Ghana were inconsistent with literature findings of previous studies , suggesting that they were peculiar to this current study in Ghana. The 19 constraints to the use of geosynthetics for civil engineering infrastructure were further validated based on the views of construction practitioners in Ghana using a structured questionnaire. Construction practitioners were the research respondents because they represent the broader stakeholder group within the construction industry in Ghana and will be the major beneficiaries if the constraints were resolved. Consequently, Table 3 presents the outcome of the study based on the views of the construction practitioners.

According to Table 2, the demographic characteristics of the respondents showed a great level of work experience with only 15.27 per cent of respondents within the 5 years bracket. Thus, the majority of the respondents had more than five years of experience. It was an indication that informed respondents participated in the survey and that contributed to the reliability of the results. However, only 5.73 per cent were female with a greater percentage of 94.27 per cent being male. This affirms the general notion that the construction industry is male-dominated. Thus, the need to intensify advocacy and sensitization regarding female involvement in engineering and technology programmes to increase female enrolment in engineering and technology-based programmes in Ghana.

The study found nineteen (19) underlying constraints to the use of geosynthetics for civil engineering infrastructure in Ghana with RSI scores ranging from 0.77 to 0.95. This was an affirmation of the constraints established from the view of the stakeholders as presented in Table 1. Thus, an indication of consensus in the view of the key stakeholders and the construction practitioners regarding the underlying constraints to the use of geosynthetics for civil engineering infrastructure in Ghana. The nineteen (19) underlying constraints were: low level of knowledge among construction practitioners on the use of geosynthetics, low level of knowledge among construction and civil engineering graduating students on geosynthetics, inadequate policies to promote the use of geosynthetics, low awareness of the economic benefits one derives from using geosynthetics, lack of schedule rates for pricing geosynthetics, insufficient curriculum provisions on geosynthetics in construction and civil engineering disciplines, lack of awareness among clients on geosynthetic-based solutions to their civil engineering needs, the conservative approach of consultants, fear of using imitated geosynthetics, perceived high cost of geosynthetics, the perception that geosynthetics is a new technology which is not tried and tested, inadequate design and installation standards regulating the use of geosynthetics in the construction industry, lack of technical know-how in design using geosynthetic technology, client's lack of experience in working with geosynthetics, lack of education on the use of geosynthetics, contractors do not have the capacity to use geosynthetics, inadequate geosynthetic laboratories to support testing of geosynthetics, lack of a geosynthetic research institute to champion research-driven campaigns for geosynthetic use in Ghana, and the use of geosynthetics is not prioritised in the manifestos of political parties in Ghana.

Relatively, low level of knowledge among construction practitioners on the use of geosynthetics with RSI score of 0.95 ranked 1st among the underlying constraints. According to [11,14], and [16] low level of knowledge on the use of geosynthetics has been a constraint to the use of geosynthetics. Ranking 2nd was the constraint, low level of knowledge among construction and civil engineering graduating

Table 1. Underlying constraints to the use of geosynthetics for civil engineering infrastructure based on the views of key stakeholders in the construction industry in Ghana

S/N	Constraints	Mean	Std. deviation	Sig. (1-tailed)	Statistical significance	Remarks
1	Low level of knowledge among construction practitioners on the use of geosynthetics	4.60	0.52	0.00	Significant	Consistent with [11]
2	Low level of knowledge among construction and civil engineering graduating students on geosynthetics	4.30	0.67	0.00	Significant	Consistent with [11,15]
3	Inadequate policies to promote the use of geosynthetics	4.40	0.70	0.00	Significant	Consistent with [14,17]
4	Low awareness of the economic benefits one derives from using geosynthetics	4.50	0.71	0.00	Significant	Consistent with [12]
5	Lack of schedule rates for pricing geosynthetics	4.90	0.32	0.00	Significant	Consistent with [12]
6	Insufficient curriculum provisions on geosynthetics in construction and civil engineering disciplines	4.70	0.48	0.00	Significant	Consistent with [12,16]
7	Lack of awareness among clients on geosynthetic-based solutions to their civil engineering needs	3.90	0.32	0.00	Significant	Consistent with [14]
8	The conservative approach of consultants	4.90	0.32	0.00	Significant	Consistent with [14,18]
9	Fear of using imitated geosynthetics	4.30	0.82	0.00	Significant	Consistent with [14]
10	Perceived high cost of geosynthetics	3.90	0.32	0.00	Significant	Consistent with [11,14,15]
11	The perception that geosynthetics are a new technology which is not tried and tested	4.60	0.84	0.00	Significant	Consistent with [11,14]
12	Inadequate design and installation standards regulating the use of geosynthetics in the construction industry	3.90	0.32	0.00	Significant	Consistent with [17]
13	Lack of technical know-how in design using geosynthetic technology	4.30	0.82	0.00	Significant	Consistent with [14]
14	Client's lack of experience in working with geosynthetics	4.60	0.84	0.00	Significant	Consistent with [14]
15	Lack of education on the use of geosynthetics	4.10	0.74	0.01	Significant	Consistent with [14]
16	Contractors do not have the capacity to use geosynthetics	4.10	0.74	0.02	Significant	Consistent with [11]
17	Inadequate geosynthetic laboratories to support testing of geosynthetics	4.10	0.57	0.00	Significant	Consistent with [16]
18	Lack of a geosynthetic research institute to champion research-driven campaigns for geosynthetic use in Ghana	3.84	0.54	0.00	Significant	Unique to Ghana study
19	The use of geosynthetics is not prioritised in the manifestos of political parties in Ghana	4.60	0.84	0.00	Significant	Unique to Ghana study

Table 2. Respondents' demographic characteristics

Main variables	Specific variables	Frequency(N)	Percentage (%)
The job role of respondents	Civil engineer	112	42.75
	Construction Technologist	35	13.36
	Building Technologist	85	32.44
	Construction Engineer	25	9.54
	Consultant: environmental engineer	1	1.91
	Consultant: civil engineer	1	0.38
	Consultant: road engineer	1	0.38
	Consultant: construction manager	1	0.38
	Consultant: quantity surveyor	1	0.38
	Total	262	100
Working experience in Ghana	5 years	40	15.27
	6 to 10 years	43	16.41
	11 to 15 years	42	16.03
	16 to 20 years	79	30.15
	Above 20 years	58	22.14
	Total	262	100
Gender	Male	247	94.27
	Female	15	5.73
	Total	262	100

Table 3. Underlying constraints to the use of geosynthetics for civil engineering infrastructure in Ghana based on the views of construction practitioners

Factor	RSI score	RSI score-ranking
Low level of knowledge among construction practitioners on the use of geosynthetics	0.95	1st
Low level of knowledge among construction and civil engineering graduating students on geosynthetics	0.93	2nd
Inadequate policies to promote the use of geosynthetics	0.91	3rd
Low awareness of the economic benefits one derives from using geosynthetics	0.90	4th
Lack of schedule rates for pricing geosynthetics	0.89	5th
Insufficient curriculum provisions on geosynthetics in construction and civil engineering disciplines	0.88	6th
Lack of awareness among clients on geosynthetic-based solutions to their civil engineering needs	0.87	7th
The conservative approach of consultants	0.85	8th
Fear of using imitated geosynthetics	0.84	9th
Perceived high cost of geosynthetics	0.83	10th
The perception that geosynthetics is a new technology which is not tried and tested	0.81	11th
Inadequate design and installation standards regulating the use of geosynthetics in the construction industry	0.80	12th
Lack of technical know-how in design using geosynthetic technology	0.79	13th
Client's lack of experience in working with geosynthetics	0.78	14th
Lack of education on the use of geosynthetics	0.77	15th
Contractors do not have the capacity to use geosynthetics	0.75	16th
Inadequate geosynthetic laboratories to support testing of geosynthetics	0.73	17th
Lack of a geosynthetic research institute to champion research-driven campaigns for geosynthetic use in Ghana	0.72	18th
The use of geosynthetics is not prioritised in the manifestos of political parties in Ghana	0.70	19th

students on geosynthetics, with RSI score of 0.93. This affirms the consensus in previous studies that an underlying constraint to the use of geosynthetics is the low level of knowledge among civil engineering graduating students [11]. This same view was affirmed by [16] in a USA survey. Likewise, [14] upheld a similar view in a UK-based study. Moreso, inadequate policies to promote the use of geosynthetics with RSI score of 0.91 ranked 3rd. This affirms the opinion that the absence of adequate policies to promote the use of geosynthetics has been an underlying constraint to the use of geosynthetics [12]. Low awareness of the economic benefits one derives from using geosynthetics with RSI score of 0.90 ranked 4th, and lack of schedule rates for pricing geosynthetics with RSI score of 0.89 ranked 5th respectively. According to [12], low awareness of the economic benefits one derives from using geosynthetics and lack of schedule rates for pricing geosynthetics have been the fundamental constraints to the use of geosynthetics. Likewise, insufficient curriculum provisions on geosynthetics in construction and civil engineering disciplines with RSI score of 0.88 ranked 6th. This is consistent with the view that underlying constraints to the use of geosynthetics hinge on the lack of provision in existing undergraduate (Bachelor's) curricula in civil engineering disciplines [14,16].

Lack of awareness among clients on geosynthetic-based solutions to their civil engineering needs with RSI score of 0.87 ranked 7th. This supports the argument by [14] that potential clients and clients alike are unaware of geosynthetic-based solutions and as a result are not in an informed position to request geosynthetic-based solutions to their needs or problems. Moreover, the conservative approach of consultants with RSI score of 0.85 ranked 8th. This affirms the view that for a breakthrough in the use of geosynthetics, consultants ought to be innovative and ingenuous in professing solutions [14,18]. Also, fear of using imitated geosynthetics with RSI score of 0.84 ranked 9th, perceived high cost of geosynthetics with RSI score of 0.83 ranked 10th, and the perception that geosynthetics is a new technology which is not tried and tested with RSI score of 0.81 ranked 11th in this Ghana study. These factors were identified by [14] in a UK-based study to have been underlying constraints to the use of geosynthetics. They were also confirmed in a Nigeria-based study by [14]. Also, inadequate design and installation standards regulating the use of geosynthetics in the construction industry with RSI score of 0.80 ranked 12th. This supports the position of [17] that the constraints to the use of geosynthetics include inadequate design and installation standards regulating the use of geosynthetics in the construction industry.

Lack of technical-know how in design using geosynthetic technology with RSI score of 0.79 ranked 13th, client's lack of experience in working with geosynthetics obtained RSI score of 0.78 and ranked 14th whereas, lack of education on the use of geosynthetics with RSI score of 0.77 ranked 15th . According to [14], constraints to the use of geosynthetics are inclusive of a lack of technical know-how in design using geosynthetic technology, the client's lack of experience in working with geosynthetics and lack of education on the use of geosynthetics.

Accordingly, ranking 16th with RSI of 0.75 is the constraint, contractors do not have the capacity to use geosynthetics. According to [11], constraining the use of geosynthetics is contractors' lack of capacity to execute the geosynthetic-based project. Moreover, inadequate geosynthetic laboratories to support testing of geosynthetics recorded RSI score of 0.73 and ranked 17th. Lack of a geosynthetic research institute to champion research-driven campaigns for geosynthetic use in Ghana with RSI score of 0.72 ranked 18th whereas the use of geosynthetics is not prioritised in the manifestos of political parties in Ghana recorded RSI score of 0.70 and ranked 19th. The lack of a geosynthetic research institute to champion research-driven campaigns for geosynthetic use in Ghana and, the use of geosynthetics is not prioritised in the manifestos of political parties in Ghana were peculiar to this Ghana study.

5. CONCLUSION

In conclusion, this study identifies nineteen (19) constraints to the use of geosynthetics in Ghana. Among the underlying constraints, low level of knowledge among construction practitioners on the use of geosynthetics ranked 1st, followed by low level of knowledge among construction and civil engineering graduating students on geosynthetics, inadequate policies to promote the use of geosynthetics, and low awareness of the economic benefits one derives for using geosynthetics in 2nd, 3rd, and 4th position respectively. Lack of a geosynthetic research institute to champion research-driven campaigns for geosynthetic use in Ghana, and the use of geosynthetics is not prioritized in the manifestos of political parties in Ghana ranked 18th and 19th respectively. However, these two constraints were found to be peculiar to this Ghana study only.

Practically, this study has reduced the numerous underlying constraints to the use of geosynthetics to nineteen (19) constraints specific to Ghana. The knowledge of the constraints is essential as it has the tendency to inform policies geared toward promoting the use of geosynthetics in Ghana. Theoretically, it has provided the basis for geosynthetics-related research and has redefined the frontier of existing constraints to geosynthetics use as it discovers, lack of a geosynthetic research institute to champion research-driven campaigns for geosynthetic use in Ghana, and the use of geosynthetics is not prioritized in the manifestos of political parties in Ghana in addition to other known constraints.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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