AN ASSESSMENT OF THE EXTENT OF APPLICATION OF GEOSYNTHETICS AS AN INTEGRAL PART OF CIVIL INFRASTRUCTURES IN GHANA

ABSTRACT

This study was informed by the lack of literature that gives a holistic account of the extent of the application of geosynthetics as an integral part of civil infrastructures on a country basis. Thus, this study determines the extent that geosynthetics have been applied as an integral part of civil infrastructures in Ghana and, establishes the relative level of application of each type of geosynthetics as an integral part of civil infrastructures in Ghana. Structured questionnaire aided in data collection. Data were analysed using frequencies, percentages, mean, standard deviation, and one sample t-test. The study revealed that there was generally a low application of geosynthetics as an integral part of civil infrastructures in Ghana. However, Ghana's case is of great concern as the application of geosynthetics was found to be only seven (7) out of the twenty-eight (28) civil infrastructures to which geosynthetics have been applied as an integral part of previous studies. Pipe projects received the most application of geosynthetics whereas geosynthetics were least applied to retaining structures. Moreso, the study further revealed that only six (6) out of the nine (9) types of geosynthetics had been applied as an integral part of civil infrastructures in Ghana namely: geopipes, geomembranes, geotextiles, geogrids, geonets, and geocells. Relatively, geopipes were the most applied geosynthetics whereas geocells were the least applied geosynthetics as an integral part of civil infrastructures in Ghana. This study serves as reference material on the extent of application of geosynthetics as an integral part of civil infrastructures in Ghana which hitherto was lacking in the construction industry in Ghana. It also serves as the basis for future studies on the application of geosynthetics as it contributes to the existing body of literature on the subject.

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Keywords: Civil Engineering, Civil Infrastructure, Construction, Geosynthetics, and Ghana.

INTRODUCTION

Civil infrastructures are the basic systems, projects, and facilities that help society to function and also maintain the environment (Fulmer, 2009). They include roads, railways, buildings, tunnels, canals, dams, ponds, manholes, pipes, earth retaining structures, wastewater treatment systems, landfill projects, water supply systems, breakwaters, airfields, and utilities, among others (Fulmer, 2009). The quest to deliver civil infrastructures within time, within budget, and in compliance with quality and sustainable measures has necessitated the application of several technologies to infrastructure delivery with an example being geosynthetics technology (Adewumi, 2018; Ait, 2021; Christoforidou et al., 2021). Geosynthetics technology is the application of geosynthetics as an integral part of man-made structures, projects, or systems (ASTM, 1994; Adewumi, 2018). The application of geosynthetics as an integral part of civil infrastructures contributes to reducing the use of natural materials (Raja, 2011; Pinho-Lopes, 2018). Thus, minimizing the depletion of natural resources within the environment. It also offers a comparative cost advantage and time efficiency in the delivery of civil infrastructures (Raja, 2011; Elragi, 2000; Khan and Singh, 2020; Wu et al., 2020; Christoforidou et al., 2021).

Additionally, the application of geosynthetics generally improves the conditions of soil, rock or earth as an integral part of civil infrastructures (GMA, 2002; Bayraktar, 2020; Oginni and Dada, 2021). Experimental evidence and field tests have in previous studies concluded that the application of geosynthetics as an integral part of civil infrastructures enhances the bearing capacity of soil more than calculated and that deformations are much lower than expected in such soil (See Ziegler, 2017; Christoforidou et al., 2021).

On the other hand, geosynthetics are planar products produced from polymeric materials and used with rock, soil, earth, or other geotechnical engineering-related materials as an integral part of man-made structures, projects, or systems (ASTM, 1994). Geosynthetics are of nine major types (Qamhia and Tutumluer, 2021; The Constructor, 2022). They are geonets, geocomposites, geogrids, geomembranes, geosynthetic clay liners, geofoams, geopipes, geotextiles, and geocells (Qamhia and Tutumluer, 2021; The Constructor, 2022).

Whereas the application of some types of geosynthetics as an integral part of civil infrastructures such as roads, buildings, landfills, wastewater treatment systems, and harbour infrastructures is known (see Zornberg, 2017; Adewumi, 2018; Khan and Singh, 2020; Oginni and Dada, 2021); little is known, if any, of country-specific studies that give a holistic account of the extent of application of geosynthetics as an integral part of civil infrastructures. This account will form the basis for deriving and deploring country-specific measures towards promoting the application of geosynthetics, owing to its numerous benefits to construction industry stakeholders. Studies on geosynthetics applications are usually country-specific as it is influenced by a multiplicity of factors such as the macro and micro economic conditions, the culture within the construction industry, and the education level of construction practitioners among others (see Raja, 2011; GSI, 2015; Adewumi, 2018). Thus, this current study, in part, contributes to addressing this gap in the literature as it seeks to determine the extent that geosynthetics have been applied as an integral part of civil infrastructures in Ghana and, establish the relative level of application of each type of geosynthetics as an integral part of civil infrastructures in Ghana.

The specific objectives that governed this study were:

- to determine the extent that geosynthetics have been applied as an integral part of civil infrastructures in Ghana;
- to establish the relative level of application of each type of geosynthetics as an integral part of civil infrastructures in Ghana.

Among others, the study serves as reference material for construction and civil engineering practitioners as well as construction industry stakeholders on the extent to which geosynthetics have been applied as an integral part of civil infrastructures in Ghana. It also provides the basis for future studies on geosynthetics applications. Moreso, in this study, construction practitioners encapsulates practicing civil engineers, construction engineers, construction technologists, building technologists, and consultants who are responsible for the design, construction ,and/or management of civil infrastructures.

APPLICATIONS AND TYPES OF GEOSYNTHETICS FOR CIVIL INFRASTRUCTURES

The application of geosynthetics as an integral part of civil infrastructures varies across nations. This is attributable to factors such as the level of knowledge among construction practitioners and clients, and the availability of geosynthetic products in the country's market, among others

(Ministry of Textile, 2013). According to Zornberg (2017) and Christoforidou et al. (2021), geosynthetics are applicable to road infrastructure. Moreso, Agrawal (2011) found geosynthetics applications to include road and harbour infrastructures. Whereas Oginni and Dada (2021) argued that geosynthetics are applicable to retaining structures and building structures. The Constructor (2022) gave a wide range of applications of geosynthetics including landfill projects, pipe projects, duct and irrigation systems, water reservoirs, and drainage projects (Muresan, 2020; The Constructor, 2022).

There are nine main types of geosynthetics (ASTM, 1994; Christoforidou, et al., 2021; Ait, 2021) with geotextiles and geogrids being the most applied geosynthetics as an integral part of civil infrastructures (Christoforidou, et al., 2021). According to Qamhia and Tutumluer (2021), and The Constructor (2022), the types of geosynthetics include geotextiles, geonets, geogrids, geomembranes, geosynthetic clay liners, geofoams, geopipes, geocomposites, and geocells (Qamhia & Tutumluer, 2021; The Constructor, 2022). Primarily, the functions of geosynthetics include separation, protection, filtration, drainage, and sealing (Ziegler, 2017).

Geotextiles

Geotextiles are permeable geosynthetic textile materials or fabrics used as an integral part of civil infrastructures and are in contact with the soil, rock, earth, or any other geotechnical substance (ASTM, 1994; Rawal et al., 2016; Patel, 2019; Khan and Singh, 2020). The functions of geotextiles include reinforcement, filtration, separation, and drainage (ASTM, 1994; Rawal et al., 2016; Patel, 2019; Khan and Singh, 2020). There is a wide application of geotextiles. This includes walls, roads, railroads, embankments, airfields, retaining structures, canals, pipelines, reservoirs, dams, bank protection, harbours, and landfills projects (Rawal et al., 2016; Qamhia & Tutumluer, 2021). Geotextiles have also been applied as an integral part of civil infrastructures such as landfills, roads, harbours, and drainage structures (Muresan, 2020). Unpaved and paved roads in airport runways, sidewalks and sand drainage layers, landfills and stone base courses, parking lots and curb areas, green areas and recreational facilities, duct banks and pipe trenches, and retaining wall structures were civil infrastructures that had geosynthetics as an integral part (Rodriguez, 2018). Geotextiles have also been applied as an integral part of roads and harbours infrastructures (Agrawal, 2011).

Geogrids

Geogrid is a polymeric structure that is unidirectional or bidirectional, and comes in the form of a manufactured surface, consisting of a normal network of integrally connected elements that can be linked by extrusion, bonding, and whose openings are larger than the constituents and are used as an integral part of civil infrastructures (Khan & Singh, 2020). Geogrids are manufactured primarily as a reinforcement or stabilizer material in addition to providing separation between soil and aggregate layers (Khan & Singh, 2020). They are able to redistribute load over a wider area, have high holding capacity, and high tensile strength, and are eco-friendly in nature (The Constructor, 2022). Applications of geogrids include reinforcement of soils for steep slopes, walls, roadway and railway bases, and foundation soils, among others (Oginni & Dada, 2021). Existing literature informs that geogrids have been applied as an integral part of civil infrastructures such as roadways, railways, retaining walls, and buildings with shallow foundations (The Constructor, 2022).

Geomembranes

Geomembranes are low-permeability or impermeable geosynthetic materials, used as an integral part of civil projects to reduce or prevent the flow of fluid through the soil (Khan & Singh, 2020). Thus, this is a category of geosynthetics with an inherent impermeable membrane. Geomembranes are in the form of a sheet. They are commonly applied as cut-offs and liners (Khan & Singh, 2020). Geomembranes are also applied as hydraulic barriers (an example is when used as canal lining), field seaming, and minimization of installation damage (Khan and Singh, 2020; The Constructor, 2022). Applications of geomembranes include ponds, landfill lining, tunnels, canal lining, environmental, transportation, oil and gas containments, and general civil infrastructures (Jeon, 2016; The Constructor, 2022).

Geonets

Geonets are polymeric structures formed by a set of continuous parallel polymeric ribs at acute angles to one another, forming a net-like pattern (Khan and Singh, 2020; The Constructor, 2022). They are used for in-plane drainage of gases or liquids (especially leachates from landfill and mining projects) and filtration of sediments contained within these fluids. Geonets are frequently laminated with geotextiles on one or both surfaces and are then referred to as drainage geocomposites (ASTM, 1994; GMA, 2002). Generally, geonets are used for drainage behind retaining structures, plaza decks, or green roofs (Koerner, Designing With Geosynthetics (6th ed.), 2012). Applications of geonets also include road construction, road widening, asphalt work, building construction and foundations, dams, artificial ponds, and water reservoirs, among others (The Constructor, 2022).

Geofoams

Geofoam is a closed-cell, super-lightweight, rigid, plastic foam (Elragi, 2000). Geofoam is used to reduce settlement below embankments, provide sound and vibration damping, reduce lateral pressure on sub-structures, and reduce stresses on rigid buried conduits and related applications (Elragi, 2000). Primarily, geofoam provides a lightweight fill below a highway, bridge approach, bridge abutment, flood control levees, basement insulations, railways, embankment, and parking lot (Elragi, 2000; Oginni and Dada, 2021). It also serves as new fills in culverts and pipelines to reduce the load over the base structure (Elragi, 2000; Oginni and Dada, 2021). It is also applicable in stadium seating, building foundations, and retaining structures (Elragi, 2000; Oginni and Dada, 2021). Using geofoam for retaining structures reduces lateral pressure, prevents settlement, and slope stabilization, and improves waterproofing (Elragi, 2000).

Geocells

Geocells are three-dimensional geosynthetic cellular structures made with novel polymeric alloy (NPA) or ultrasonically welded high-density polyethylene (HDPE) strips (GMA, 2002; Yuu et al., 2008). Applications of geocells include channel protection, erosion control, road construction, landfills, landscaping, mining operations, structural reinforcement for load support and earth retention, protective linings for channels and hydraulic structures, provides support for static and dynamic loads on weak subgrade soils, and green infrastructure projects (GMA, 2002; Hegde, 2020). Geocells provide both a transfer of load through the cellular structures and physical containment of a depth of soil (Hegde, 2020). Geocells are also applicable to foundations, waste containment, embankments of roads, and railway structures (Vibhoosha et al., 2021).

Geosynthetic clay liners

Geosynthetic clay liners consist of thin layers of bentonite clay sandwiched between two layers of geotextiles and bonded to a geomembrane (United States Environmental Protection Agency, 2001; The Constructor, 2022). The two layers of geotextiles are stitched together by a sewing process (needle-punched non-woven) thereby creating a perfectly balanced mat that has an internal shear resistance (United States Environmental Protection Agency, 2001; The Constructor, 2022). Anytime geosynthetic clay liners come into contact with water, the bentonite in the mat puffs up thereby creating a waterproof mineral layer (The Constructor, 2022). Application of geosynthetic clay liners includes canals, stormwater impoundments and wetlands, highway construction, secondary containment, landfill liners, landfill caps, mines, and general civil infrastructures (United States Environmental Protection Agency, 2001; The Constructor, 2022).

Geopipes

Geopipes are solid-wall or perforated polymeric pipes for the drainage of fluid (gases and liquids). They are primarily used for leachate collection and in instances of high compressive loads (The Constructor, 2022). Geopipes are preferred for landfill use as a means for the collection and quick drainage of the leachate to a sump, and removal system (The Constructor, 2022). Further applications of geopipes include subdrainage for buildings, roads, oil and gas production, sewer and wastewater transportation, and duct and irrigation systems (The Constructor, 2022)

Geocomposites

Geocomposites are geosynthetics formed by a mixture of two or more geosynthetics such as geomembrane-geonet, geonet-geotextile, and geogrid-geotextile, among others (Oginni & Dada, 2021). The primary functions of geocomposites include separation, reinforcement, drainage, filtration, stabilization, containment, and erosion control (Koerner, Designing With Geosynthetics (6th ed.), 2012). The application of geocomposites is prevalent in road construction, drainage segment, pavement base course or edge drains, rooftops, trench drains, tunnels in railways and roads, retaining walls, and bridge abutments, among others (The Constructor, 2022).

SUMMARY OF LITERATURE FINDINGS ON THE TYPES AND THE APPLICATIONS OF GEOSYNTHETICS

Thus, from the review of existing literature, it was revealed that nine types of geosynthetics have been applied as an integral part of some specific civil infrastructures. The civil infrastructures were twenty-eight (28) in number, namely: highways, railroads, embankments, duct and irrigation systems, oil and gas transportation, airfields, retaining structures, canals, pipe projects, water reservoirs, harbours, dams, landfills, green areas, and recreational facilities, stormwater impoundment, wetlands, sidewalks, parking lots and curb areas, stadia, bridges, levees, buildings, tunnels, plaza decks, culverts, ponds, channels, and

Civil infrastructures	Geotextiles	Geogrids	Geomembranes	Geonets	Geofoams	Geosynthetic clay liners	Geopipes	Geocells	Geocomposites
Highways	X	X		x	X	x	x	X	
Railroads	X				X		x	x	
Embankments	X				X				
Duct and irrigation systems							x		
Oil and gas transportation							x		
Airfields	X								
Retaining structures	X			x	X				
Canals	X	x	X		X				x
Pipe projects	X								
Water reservoirs	X			x					
Harbours	X								
Dams	X			x					
Landfills	X				x	x		x	x
Green areas and recreational facilities	X				x			x	
Stormwater impoundment						x			
Wetlands						x			
Sidewalks	X								x
Parking lots and curb areas	X				X				
Stadia	X				x				
Bridges					x				
Levees					x				
Buildings		x		x	x	x			
Tunnels			x						
Plaza decks				x					
Culverts					x				
Ponds			x						
Channels					x				
Drainage									x

Table 1: Civil infrastructures-geosynthetics application matrix from previous studies

METHODOLOGY

This study follows a cross-sectional research design. This is because the data collected pertains to only what prevailed within the period of data collection. There is a tendency that it might change with time. Firstly, the literature was reviewed which aided in identifying the types of geosynthetics and the applications of each type of geosynthetic as an integral part of civil infrastructures. The second stage was the use of a structured questionnaire to solicit the views of construction practitioners on the extent that geosynthetics have been applied as an integral part of civil infrastructures in Ghana and, the relative level of application of each type of geosynthetics as an integral part of civil infrastructures in Ghana, based on their knowledge and/or experience. Experience means having had the opportunity of applying or supervising the application of geosynthetics as an integral part of civil infrastructures over a period of at least five (5) years. Knowledge means being cognisant of the application of geosynthetics as an integral part of civil infrastructures in Ghana. The respondents included construction practitioners from 257 construction firms who belong to the Association of Building and Civil Engineering Contractors of Ghana (ABCECG). This sample size of construction firms was determined based on Neuman's (2006) principle that, for a population of size around 1500, 20% should be sampled (see Neuman, 2006; Aigbavboa, 2014). 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 and Construction Review Online (2020). ABCECG was chosen as the study population because it is the association for building and civil engineering contractors (construction firms) in Ghana with members in all 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 have the knowledge and/or experience in the applications of geosynthetics as an integral part of civil infrastructures and the relative application of each type of geosynthetics as an integral part of civil infrastructures. In addition, the views of five (5) construction industry consultants were purposively added. Within each consulting firm, information was sought from practitioners within the field of civil engineering, construction engineering, construction technology, or building technology who have the knowledge and/or experience regarding the application of geosynthetics as an integral part of civil infrastructures. Thus, the views of 262 construction practitioners were sought regarding the application of geosynthetics as an integral part of civil infrastructures and the relative application of each type of geosynthetics as an integral part of civil infrastructures. In this study, construction practitioners embodied construction practitioners with both consultants and contractors (construction firms).

Responses were solicited from the construction practitioners regarding the application of geosynthetics as an integral part of civil infrastructures and the relative application of each type of geosynthetics as an integral part of civil infrastructures based on a 5-point scale, where (1) represents a strongly disagree, (2) is disagrees, (3) is neutral, (4) agrees, and (5) denotes strongly agree in measuring the responses from the research respondents. 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 given when requested. Data were analysed using the standard deviation and the mean. One sample t-test was further used in analysing the data. This aid in comparing the response mean value to the population/hypothesized mean to ascertain the level of statistical significance of the responses obtained from the research respondents. Accordingly, a hypothesized mean was set at 3.5 (see Tengan et al., 2020). The significance level was also set at 95% in accordance with predictable risk levels (see Tengan et al., 2020). Any significant (1-tailed) value (p-value) not exceeding 0.05 was considered statistically significant (see Tengan et al., 2020).

RESULTS AND DISCUSSIONS

Table 2. Respondents' demographic characteristics

Main variables	Specific variables	Frequency(N)	Percentage (%)
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	5	1.91
	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	257	100

The demographic characteristics of the respondents from Table 2 suggest a great level of work experience. This was an indication that the research respondents were well informed and experience would be brought to bear in response to the questions on the questionnaire. The percentage of male and female respondents only reflected that the construction industry in Ghana was a male-dominated sector and there was the need to cautiously bridge the male-female ratio in construction programs.

Table 3: the extent of application of geosynthetics to civil infrastructures in Ghana

Civil infrastructures	Mean	Mean score ranking	Standard deviation	Sig(1-tailed)	Statistical significance
Pipe projects	2.46	1st	0. 72	0.00	Yes
duct and irrigation systems	2.32	2nd	0.59	0.00	Yes
Building structures	2.30	3rd	0.57	0.00	Yes
Water reservoirs	2.28	4th	0.57	0.00	Yes
Landfill infrastructure	2.11	5th	0. 72	0.00	Yes
Highways infrastructure	1.96	6th	0.86	0.00	Yes
Retaining structures	1.71	7th	0. 73	0.00	Yes

From Table 3, standard deviation values were all below one (1.0). This was an indication that there was consistency in the data collected from the research respondents and thus, there was little variability in the views they expressed. Therefore, responses were reliable and accurate. Moreso, all the p-values for the one-tailed test from Table 3, indicated a strong statistical significance of the data collected. All, the t-test p-values were 0.000.

The results revealed that geosynthetics had been applied as an integral part of civil infrastructure to only seven (7) civil infrastructures in Ghana out of the twenty-eight (28) civil infrastructures identified from the literature review. This implied that the application of geosynthetics as an integral part of civil infrastructures was low in Ghana and the construction practitioners in Ghana were not familiar with all the nine types of geosynthetics. This could be attributed to the lack of education on geosynthetics applications among construction practitioners in Ghana as well as the lack of availability of certain types of geosynthetics in Ghana (see Raja, 2011; Ministry of Textile, 2013).

But that notwithstanding, relatively, pipe projects were the civil infrastructure that received the most application of geosynthetics. It recorded a mean score of 2.46 and ranked 1st. This was consistent with findings by The Constructor (2022) which among others revealed the application of geosynthetics as an integral part of civil infrastructures such as pipe projects and duct and irrigation systems. Specifically, Rodriguez (2018) identified the application of geotextiles as an integral part of pipe projects whereas Elragi (2000) and Oginni and Dada (2021) identified the application of geofoams as a fill material around pipe projects. The 2nd ranked civil infrastructure that geosynthetics have been applied as an integral part in Ghana was duct and irrigation systems with a mean score of 2.32. This was followed by building structures with a mean score of 2.30. According to Oginni & Dada (2021), geosynthetics are applicable to retaining structures and building structures. However, in the case of Ghana retaining structures ranked 7th with a mean score of 1.71. Moreso, water reservoirs with a mean score of 2.28 ranked 4th. It was followed by landfill infrastructure with a mean score of 2.11 ranking 5th, and highways infrastructure with a mean score of 1.96 ranking 6th. According to Rawal et al. (2016) and Qamhia and Tutumluer (2021) applications of geosynthetics as an integral part of civil infrastructure include reservoirs, landfill, and highways infrastructures. In relation to landfill infrastructure, geosynthetics such as geomembranes were found to have been applied as an integral part of landfill infrastructure according to Jeon (2016), whereas Muresan (2020) also identified geotextiles as an integral part of landfill infrastructure. Specifically, Oginni and Dada (2021) found the application of geogrids as an integral part of highways whereas Rodriguez (2018) found the application of geotextiles as an integral part of highways infrastructure. Moreso, Vibhoosha et al. (2021) also identified the application of geocells as an integral part of highway infrastructure to improve the soil conditions at the base course.

Table 4: Mean score ranking of the relative application of each type of geosynthetic as an integral part of civil infrastructures in Ghana

Geosynthetic(s)	Mean score	Ranking
Geopipes	4.12	1st

Geomembranes	3.11	2^{nd}
Geotextiles	2.24	3^{rd}
Geogrids	0.71	4^{th}
Geonets	0.67	5^{th}
Geocells	0.20	6^{th}
Overall mean score	**1.84**	

Table 4 presents the outcome of the mean score ranking of the relative application of each type of geosynthetic as an integral part of civil infrastructures in Ghana. It was revealed that only six (6) out of the nine (9) geosynthetics have been applied to civil infrastructures in Ghana. This is attributable to a lack of education on geosynthetics among construction practitioners and a lack of availability of all types of geosynthetics in the construction industry in Ghana. Lack of education among construction practitioners by Raja (2011), GSI (2015), Adewumi (2018) and Qamhia and Tutumluer (2021) and lack of availability Ministry of Textile (2013) were earlier found to have saddled the application of geosynthetics as an integral part of civil infrastructures in some national contexts. GSI (2015) further argued that the low level of application of geosynthetics is attributable to a lack of geosynthetic content in the curriculum for civil engineering and related programmes.

Furthermore, there was generally a low application of geosynthetics as an integral part of civil infrastructures in Ghana. An overall mean score of 1.84 was recorded which was less than the hypothesised/population mean of 3.5. Specifically, the results indicated that apart from geopipes which recorded a mean score of 4.12, all the other types of geosynthetics recorded mean scores that were lower than the population/hypothesised mean of 3.5. This was an indication that there was generally a low application of geosynthetics to civil infrastructures in Ghana. This was consistent with the findings by Oginni and Dada (2021) that the application of geosynthetics as an integral part of civil infrastructures was low globally. This was attributable to the general lack of education on geosynthetics among construction practitioners as observed by Raja (2011), GSI (2015), Adewumi (2018) and Qamhia and Tutumluer (2021). Additionally, this study unravelled that relatively, the geopipes were the most applied geosynthetics as an integral part of civil infrastructures in Ghana. It ranked 1^{st} with a mean score of 4.12. Whereas the least ranked was geocells with a mean score of 0.20, ranking 9^{th}.This contrast the argument that geotextile and geogrids were the dominant applied geosynthetics to civil infrastructures (Christoforidou, et al., 2021).

CONCLUSIONS

This current study determines the extent that geosynthetics have been applied as an integral part of civil infrastructures in Ghana and, establishes the relative level of application of each type of geosynthetics as an integral part of civil infrastructures in Ghana. The study concludes that the extent of application of geosynthetics as an integral part of civil infrastructures is low in Ghana as pertains globally. However, Ghana's case is of great concern as geosynthetics have been applied as an integral part of only seven (7) out of twenty-eight (28) civil infrastructures revealed in previous studies namely: pipe projects, duct and irrigation systems, building structures, water reservoirs, landfill infrastructures, highways infrastructures, and retaining structures. Pipe projects received were the civil infrastrue that received the most application of geosynthetics whereas geosynthetics were least applied to retaining structures. Moreso, this study concludes that only six (6) out of the nine (9) geosynthetics have been applied as an integral part of civil infrastructures in Ghana namely: geopipes, geomembranes, geotextiles, geogrids, geonets, and geocells. Relatively geopipes were the most applied geosynthetics as an integral part of civil infrastructures whereas geocells were the least applied as an integral part of civil infrastructures in Ghana.

Thus comparing the outcome of this Ghana study with existing literature, it was evidenced that the extent of application of geosynthetics as an integral part of civil infrastructures as well as the relative application of each type of geosynthetics is country-specific and thus, it will be inaccurate to generalize the findings to be the same across nations. Hence, the findings of this study are limited to Ghana only though they may provide lessons for countries such as Nigeria, Angola, and Togo whose construction industry shares many characteristics with Ghana. This study serves as reference material on the application of geosynthetics as an integral part of civil infrastructures in Ghana which hitherto was not in existence. This is of enormous benefit to construction practitioners such as civil engineers, construction technologists, building technologists, and other stakeholders within the construction industry in Ghana. It also has the tendency of informing policies aimed at enhancing the application of geosynthetics in Ghana and promoting geosynthetics application as an integral part of civil infrastructures in Ghana. It will serve as the basis for future studies on geosynthetics applications as it contributes to the existing body of literature on the subject.

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