African Journal of Advanced Pure and Applied Sciences (AJAPAS)
Online ISSN: 2957-644X
Volume 5, Issue 2, 2026
Page No: 490-501
Website: https://aaasjournals.com/index.php/ajapas/index
ISI 2025: 1.126 SJIFactor 2024: 6.752 معامل التأثير العربي: 1.62

Barriers and Strategic Solutions for the Adoption of Sustainable Concrete in Developing Countries: A Case Study of Tobruk, Libya

Ahmed Fathi Mohammed Labeedi [1], Abdullah Abdulsalam Abdullah Abkhatirh [2]
[1,2] Civil Engineering Department, Higher Institute of Science and Technology, Tobruk, Libya

المعوقات والحلول الاستراتيجية لتبني الخرسانة المستدامة في البلدان النامية: دراسة حالة طبرق، ليبيا

أحمد فتحي محمد لبيدي [1] ، عبد الله عبد السلام عبد الله [2]
[2،1] قسم الهندسة المدنية، المعهد العالي للعلوم والتقنية، طبرق، ليبيا

[*]Corresponding author: Ahmed.labedi@gmail.com

Received: April 19, 2026	Accepted: June 25, 2026	Published: June 29, 2026

Abstract
The construction sector significantly contributes to global carbon emissions and resource depletion, with concrete production alone accounting for 8–9% of anthropogenic CO_2 emissions worldwide. Despite the environmental and economic benefits of sustainable concrete, its adoption remains limited in many developing countries, including Libya. This study aims to identify and assess the critical barriers hindering sustainable concrete adoption in Tobruk, Libya, and propose strategic solutions tailored to the local context. A quantitative approach was employed, utilizing a structured questionnaire distributed to 52 construction professionals, including civil engineers, project managers, contractors, and concrete industry employees. Nineteen barriers were identified from the literature and classified into four categories: knowledge and awareness, economic and resources, technical and implementation, and regulatory and cultural barriers. Data was analyzed using descriptive and inferential statistics, including Mean Item Score (MIS) and Kruskal-Wallis tests. Results revealed that knowledge and awareness barriers were not critical (MIS 2.23–3.71), while economic and resource barriers (MIS 3.46–3.79), technical and implementation barriers (MIS 3.54–3.79), and regulatory and cultural barriers (MIS 3.23–3.81) were significantly influential. The most critical barriers included lack of demonstration projects (MIS 3.81), low demand for sustainable materials (MIS 3.79), shortage of skilled labor (MIS 3.79), passive industry culture (MIS 3.79), and high material costs (MIS 3.77). Based on these findings, strategic solutions were developed across four categories, including financial incentives, workforce development, research and development funding, and regulatory reform. This study contributes to the limited body of knowledge on sustainable concrete adoption in North Africa and provides actionable recommendations for policymakers, construction professionals, and stakeholders in similar developing contexts.

Keywords: Sustainable Concrete, Barriers, Developing Countries, Libya, Construction Industry, Green Building.

الملخص
يُساهم قطاع الإنشاءات بشكل كبير في الانبعاثات الكربونية العالمية واستنزاف الموارد، حيث يتسبب إنتاج الخرسانة وحده في 8-9% من إجمالي انبعاثات ثاني أكسيد الكربون الناجمة عن الأنشطة البشرية حول العالم. وعلى الرغم من الفوائد البيئية والاقتصادية للخرسانة المستدامة، إلا أن اعتمادها لا يزال محدوداً في العديد من الدول النامية، بما في ذلك ليبيا.

تهدف هذه الدراسة إلى تحديد وتقييم العوائق الحرجة التي تعوق تبني الخرسانة المستدامة في مدينة طبرق بليبيا، واقتراح حلول إستراتيجية تتناسب مع السياق المحلي. تم استخدام منهج كمي، يعتمد على استبيان مهيكل تم توزيعه على 52 من المهنيين في قطاع الإنشاءات، بمن فيهم المهندسون المدنيون، ومدراء المشاريع، والمقاولون، والعاملون في صناعة الخرسانة.
تم تحديد تسعة عشر عائقاً من الأدبيات السابقة وتصنيفها إلى أربع فئات: عوائق المعرفة والوعي، العوائق الاقتصادية والموارد، العوائق الفنية والتنفيذية، والعوائق التنظيمية والثقافية. وتُمت تحليل البيانات باستخدام الإحصاء الوصفي والاستدلالي، بما في ذلك متوسط درجات العناصر (MIS) واختبار "كروسكال-واليس."
أظهرت النتائج أن عوائق المعرفة والوعي لم تكن حرجة (MIS 2.23–3.71) ، بينما كانت العوائق الاقتصـــادية والموارد (MIS 3.46–3.79)، والعوائق الفنية والتنفيذية (MIS 3.54–3.79) ، والعوائق التنظيمية والثقافية (MIS 3.23–3.81) ذات تأثير كبير.
وشـــملت العوائق الأكثر حرجاً: غياب المشـــاريع التوضـــيحية (النموذجية).(MIS 3.81) ، انخفاض الطلب على المواد المســـتدامة (MIS 3.79). ، نقص العمالة الماهرة.(MIS 3.79) ، الثقافة الســـلبية في القطاع.(MIS 3.79) ، الارتفاع في تكاليف المواد (MIS 3.77).
وبناءً على هذه النتائج، تم تطوير حلول إستراتيجية موزعة على أربع فئات، شملت: الحوافز المالية، وتطوير القوى العاملة، وتوفير التمويل للبحث والتطوير، والإصلاح التنظيمي. تُسهم هذه الدراسة في إثراء حصيلة المعرفة المحدودة حول تبني الخرسانة المستدامة في شمال إفريقيا، وتقدم توصيات قابلة للتطبيق لصناع القرار، والمهنيين في قطاع الإنشاءات، وأصحاب المصلحة في البيئات النامية المشابهة.
الكلمات المفتاحية :الخرسانة المستدامة، العوائق، الدول النامية، ليبيا، قطاع الإنشاءات، البناء الأخضر.

1. Introduction

1.1 Background

The construction sector is a major contributor to global environmental degradation, responsible for approximately 35% of worldwide carbon dioxide emissions and generating 45–65% of waste disposed in landfills (Lima et al., 2021). Furthermore, the sector accounts for approximately 30% of global greenhouse gas emissions, with 18% attributable to the transportation and processing of construction materials (Lima et al., 2021). Concrete, being the most widely used construction material, significantly contributes to these impacts, accounting for 8–9% of total anthropogenic CO_2 emissions (Assi et al., 2018). The excessive use of concrete also results in extensive depletion of natural resources, including natural aggregates. Gravels and sand represent the majority of commonly extracted natural resources globally, with 28.6 gigatons extracted annually as of 2010 (Tamanna, Tuladhar and Sivakugan, 2020). Sand, despite its abundance on the earth's surface, is a limited natural resource that faces imminent exhaustion. Excessive sand extraction causes not only material shortages but also adverse environmental impacts, including coastal erosion, groundwater contamination, and increased flood and storm surge damage (Tamanna, Tuladhar and Sivakugan, 2020).

In response to these challenges, the construction industry is progressively adopting sustainable practices. Sustainable concrete, which incorporates waste materials as substitutes for virgin components such as cement and sand, offers numerous advantages, including superior strength, improved durability, reduced permeability, and decreased environmental footprint (Liew, Sojobi and Zhang, 2017). Alternative materials such as fly ash, silica fume, waste glass, recycled plastic, and construction demolition waste have demonstrated promising results in concrete applications (Hashmi et al., 2022; Mehta and Ashish, 2020; Askar, Al-Kamaki and Hassan, 2023; Xiao et al., 2018).

Despite these benefits, the adoption of sustainable concrete remains limited, particularly in developing countries. While developed nations have made significant progress in green building practices, developing countries continue to rely heavily on conventional concrete, perpetuating environmental degradation and resource depletion (Davies and Davies, 2017). Understanding the barriers to sustainable concrete adoption is essential for developing effective strategies to overcome these obstacles (Osuizugbo et al., 2020).

1.2 The Libyan Context

Libya presents a unique case study for examining barriers to sustainable concrete adoption. The country has experienced significant reconstruction and development activity in recent years, yet sustainable construction practices remain in their infancy (Khalil, Rathnasinghe and Kulatunga, 2021). Studies have shown a low degree of proficiency in green building in Libya, with inadequate adoption of sustainable practices in ongoing construction projects (Awaili, Uzunoglu and Özden, 2020). Key factors contributing to this limited adoption include lack of awareness, insufficient regulations, high costs, limited material availability, and inadequate financial incentives (Abdausamea, Saaed and Ali, 2018; Khalil, Rathnasinghe and Kulatunga, 2021).

Tobruk, a growing city in eastern Libya, serves as an appropriate study area due to its increasing construction activity and strategic importance as a border region near Egypt. The city has experienced development projects aimed at creating residential areas, commercial hubs, and public infrastructure (Khalil, Rathnasinghe and Kulatunga, 2021). This research focuses on Tobruk formulating suitable measures for promoting sustainable concrete construction in the region. Figure 1 shows the geographical location of Tobruk."

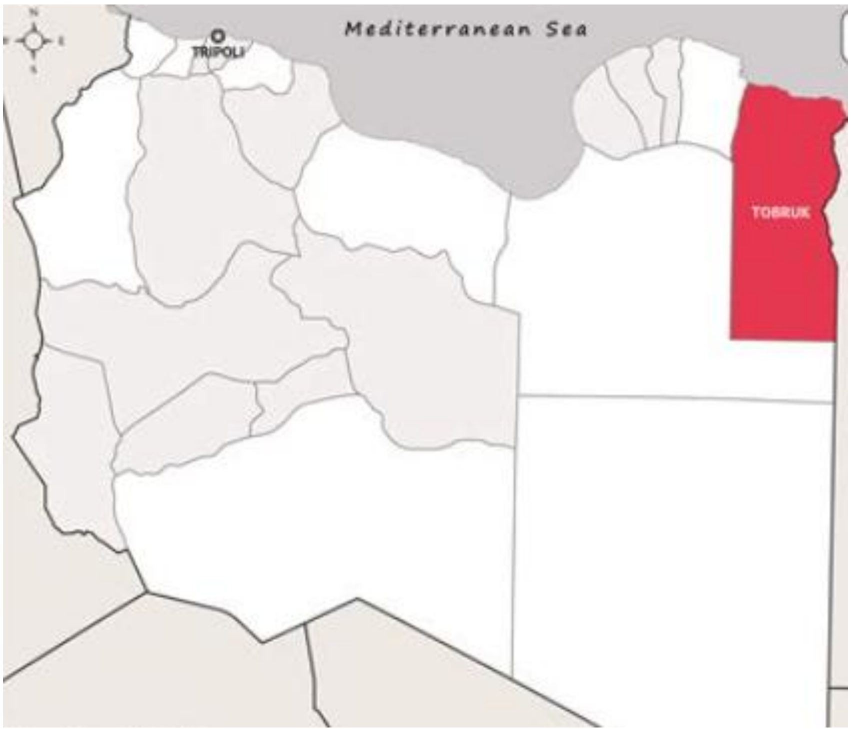

Figure 1: Location Map of Tobruk, Libya (Source: Google Earth)

1.3 Research Gap and Objectives

While several studies have examined general barriers to sustainable construction in Libya, there is a notable lack of research specifically addressing barriers to sustainable concrete adoption (Khalil, Rathnasinghe and Kulatunga, 2021; Awaili, Uzunoglu and Özden, 2020). This research aims to fill this gap by conducting a focused assessment of barriers to sustainable concrete adoption in Tobruk, Libya. The objectives are:

1. To identify and assess the most common critical barriers hindering sustainable concrete adoption in Tobruk, Libya.
2. To categorize these barriers and determine their relative significance.
3. To propose effective solutions and strategies tailored to the Libyan context.

1.4 Significance of the Study

This research makes significant contributions by addressing the urgent need for sustainable concrete adoption in Libya. The findings provide evidence-based insights for policymakers, construction professionals, and stakeholders to overcome existing obstacles. The study also contributes to the global sustainable development dialogue by offering practical solutions from the perspective of a developing North African context, thereby filling a critical gap in the literature.

Literature Review

2.1 Introduction

Sustainable construction has emerged as a global priority, driven by the need to balance economic development, social well-being, and environmental protection (Tunji-Olayeni, Kajimo-Shakantu and Osunrayi, 2020). The construction sector significantly contributes to global carbon emissions and resource depletion, accounting for approximately 35% of worldwide CO_2 emissions and 45–65% of waste disposed in landfills (Lima et al., 2021). Concrete, as the most widely used construction material, is responsible for 8–9% of global anthropogenic CO_2 emissions (Assi et al., 2018). Despite advancements in sustainable concrete technologies, their adoption remains limited in developing countries, including Libya. This review synthesizes existing knowledge on sustainable construction practices, drivers and materials for sustainable concrete, and barriers to adoption, with particular emphasis on developing country contexts.

2.2 Sustainable Construction Practices and the Libyan Context

Sustainable construction prioritizes financial, social, and environmental considerations throughout the building process (Osuizugbo et al., 2020). However, developing countries continue to lag behind developed nations in adopting these practices (Davies and Davies, 2017). In Libya, sustainable construction remains in its infancy. Studies have shown a low degree of proficiency in green building, with inadequate adoption of sustainable practices in ongoing projects (Awaili, Uzunoglu and Özden, 2020). Khalil, Rathnasinghe and Kulatunga (2021) identified that Libya's sustainable construction sector suffers from low market awareness, ineffective regulations, high costs, and limited material resources. The construction industry lacks defined policies, financial incentives, and skilled human resources necessary for sustainability. Abdausamea, Saaed and Ali (2018) further noted the absence of complex updated green equipment and construction technologies alongside a sufficiently trained green building workforce. These findings highlight the urgent need for targeted research on sustainable concrete adoption in Libya.

2.3 Drivers and Materials for Sustainable Concrete

The construction industry is progressively using sustainable concrete due to the disadvantages of traditional concrete and the various advantages that come with sustainable alternatives (Liew, Sojobi and Zhang, 2017). Sustainable concrete delivers superior strength, longer life, improved usability, stronger defense to acid attacks, decreased permeability, and mitigation of plastic shrinkage cracking (Liew, Sojobi and Zhang, 2017). These features lead to quicker manufacturing, shorter curing times, lower construction costs, faster project finishing, reduced upkeep costs, and a longer lifespan for building projects.

Several materials are available for sustainable concrete production. Fly ash, a byproduct of coal-fired power plants, can decrease cement demand by twenty percent and enhance concrete strength (Hashmi et al., 2022; Afrin, Huda and Abbasi, 2021). Silica fume, a byproduct of ferrosilicon alloy production, improves compressive, splitting tensile, and flexural strength (Mehta and Ashish, 2020; Wang et al., 2022). Waste glass, when incorporated as a fine aggregate in amounts of 20–30%, increases compressive strength beyond ordinary concrete (Hamada et al., 2022; Ahmed and Rana, 2023). Polyethylene terephthalate (PET) plastic waste enhances tensile, bending, and compression strength (Askar, Al-Kamaki and Hassan, 2023; Bamigboye et al., 2021). Construction and demolition waste, with up to 30% replacement, shows positive or no significant negative effect on mechanical performance (Xiao et al., 2018; Kumar et al., 2022). Despite these benefits, adoption remains constrained by multiple barriers.

2.4 Barriers to Sustainable Concrete Adoption

The barriers to sustainable concrete adoption can be categorized into four main groups (Al-Otaibi, 2024; Davies and Davies, 2017; Osuizugbo et al., 2020).

Knowledge and Awareness Barriers: Limited awareness or comprehension of the advantages of sustainable concrete structures prevents adoption (Nilimaa, 2023). Construction clients and other participants show low interest in sustainability issues (Aghimien et al., 2018). AlSanad (2015) stated that willingness to carry out green construction practices depends on awareness, knowledge, and comprehension. However, Osuizugbo et al. (2020) reported that in Nigeria, knowledge and awareness barriers were among the least concerning factors, suggesting contextual variation.

Economic and Resource Barriers: High cost of sustainable materials (Nilimaa, 2023), limited availability of sustainable materials (Jaradat et al., 2024), and uncertainty about material quality (Ahmed et al., 2023) pose significant obstacles. Davies and Davies (2017) reported that added costs of sustainable materials range between 1–25% on average. The lack of market demand (Badraddin et al., 2021) further compounds these economic challenges.

Technical and Implementation Barriers: Lack of required tools and methods (Onososen, Osanyin and Adeyemo, 2019), shortage of skilled labor (Aghimien et al., 2018), lack of sustainable technologies (Nilimaa, 2023; Zulu et al., 2023), and shortage of professional designers (Zollo et al., 2023) all significantly hinder adoption. These elements have systematically undermined the policies and practices of sustainability that the construction industry requires.

Regulatory and Cultural Barriers: Absence of clear guidelines (Badraddin et al., 2021), client resistance and lack of understanding (Onososen, Osanyin and Adeyemo, 2019), passive industry culture (Nilimaa, 2023), lack of sustainability criteria in bidding processes (Durdyev et al., 2018), misconceptions about construction costs (Ifije and Aigbavboa, 2020), and lack of demonstration projects (Aghimien et al., 2018) all contribute to low adoption rates.

2.5 Research Gap

While several studies have examined general barriers to sustainable construction in Libya (Khalil, Rathnasinghe and Kulatunga, 2021; Awaili, Uzunoglu and Özden, 2020), none have specifically assessed the barriers to sustainable concrete adoption. This research aims to fill this gap by focusing specifically on sustainable concrete, evaluating critical barriers for accurate assessment, and suggesting effective solutions tailored to the Libyan context.

3. Methodology

3.1 Research Design

This study employed a quantitative research approach consisting of two phases: (1) identification and assessment of barriers to sustainable concrete adoption, and (2) development of strategic solutions. Figure 2 illustrates the methodological framework adopted for this study.

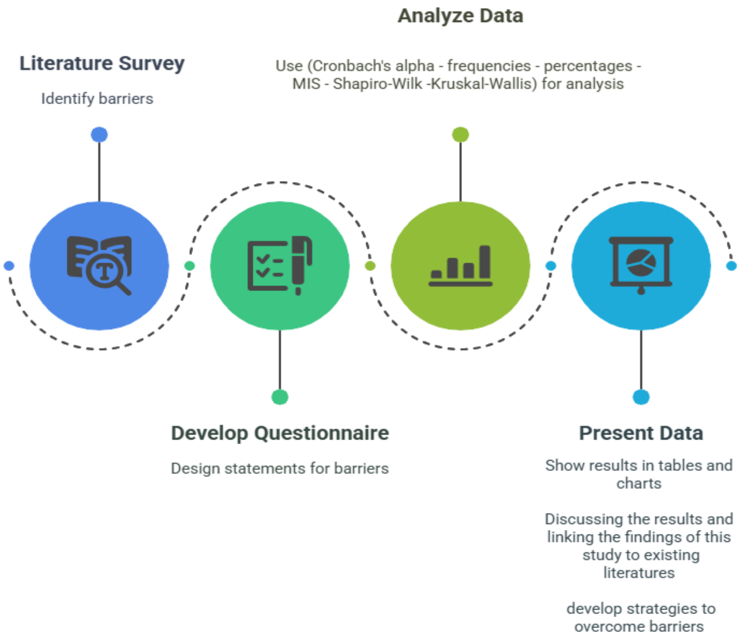

Figure 2: Research Methodological Framework

3.2 Literature Review

A comprehensive literature review was conducted to identify barriers to sustainable construction across Arab, African, and Asian countries. Nineteen barriers were identified and classified into four categories: knowledge and awareness, economic and resources, technical and implementation, and regulatory and cultural barriers (Table 1).

Table 1: Classification of Barriers

Category	Barriers	Reference
Knowledge& Awareness	BR1: Low knowledge about sustainable concrete	Nilimaa (2023)
	BR2: Lack of effort to learn	Osuizugbo et al. (2020)
	BR3: Unwillingness to adopt	Alsanad (2015)
	BR4: Lack of interest in sustainability	Aghimien et al. (2018)
Economics & Resources	BR5: High cost of materials	Nilimaa (2023)
	BR6: Limited availability	Jaradat et al. (2024)
	BR7: Uncertainty about quality	Nilimaa (2023)
	BR8: Lack of demand	Badraddin et al. (2021)
Technical & Implementation	BR9: Limited methods and tools	Onososen et al. (2019)
	BR10: Shortage of skilled labor	Aghimien et al. (2018)
	BR11: Lack of technologies	Nilimaa (2023)
	BR12: Lack of professional designers	Zollo et al. (2023)
Regulatory & Cultural	BR13: Absence of clear guidelines	Badraddin et al. (2021)
	BR14: Client resistance	Onososen et al. (2019)
	BR15: Passive industry culture	Nilimaa (2023)
	BR16: No sustainability in bidding	Durdyev et al. (2018)
	BR17: Misconceptions about cost	Ifije and Aigbavboa (2020)
	BR18: Lack of demonstration projects	Aghimien et al. (2018)
	BR19: Lack of government support	Awaili et al. (2020)

3.3 Quantitative Method

3.3.1 Data Collection (Questionnaire)

A structured questionnaire was designed based on the literature review. The questionnaire comprised two sections: (1) respondents' demographics, and (2) assessment of 19 barriers using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The questionnaire was validated through face validity by six construction experts from academic and practical fields. Reliability was confirmed using Cronbach's alpha test ($\alpha = 0.768$), indicating acceptable internal consistency.

The questionnaire was distributed using snowball sampling due to the absence of an official database of construction professionals in Tobruk. A total of 52 valid responses were collected over one month via Google Forms and social media platforms. Respondents included civil engineers (55.8%), project managers (17.3%), contractors (15.4%), and concrete industry employees (11.5%). Over 53.8% held bachelor's degrees, 32.7% held master's degrees, and 77% had more than five years of experience.

3.3.2 Data Analysis Methods

Data were analyzed using SPSS software. Descriptive statistics included frequencies, percentages, and Mean Item Scores (MIS). Interpretation was based on the following framework: 1.00–1.49 (Not significant), 1.50–2.49 (Slightly significant), 2.50–3.49 (Averagely significant), 3.50–4.49 (Significant), 4.50–5.00 (Very significant). Inferential statistics employed the Kruskal-Wallis test to examine differences between professional groups ($\alpha = 0.05$).

4. Results

The results demonstrate that professionals in general evaluated these barriers in a way that indicates that the barriers related to knowledge and awareness are not critical. A large percentage of the respondents indicated that they have good knowledge of sustainable concrete. Figure 3 illustrates the mean item scores for knowledge and awareness barriers.

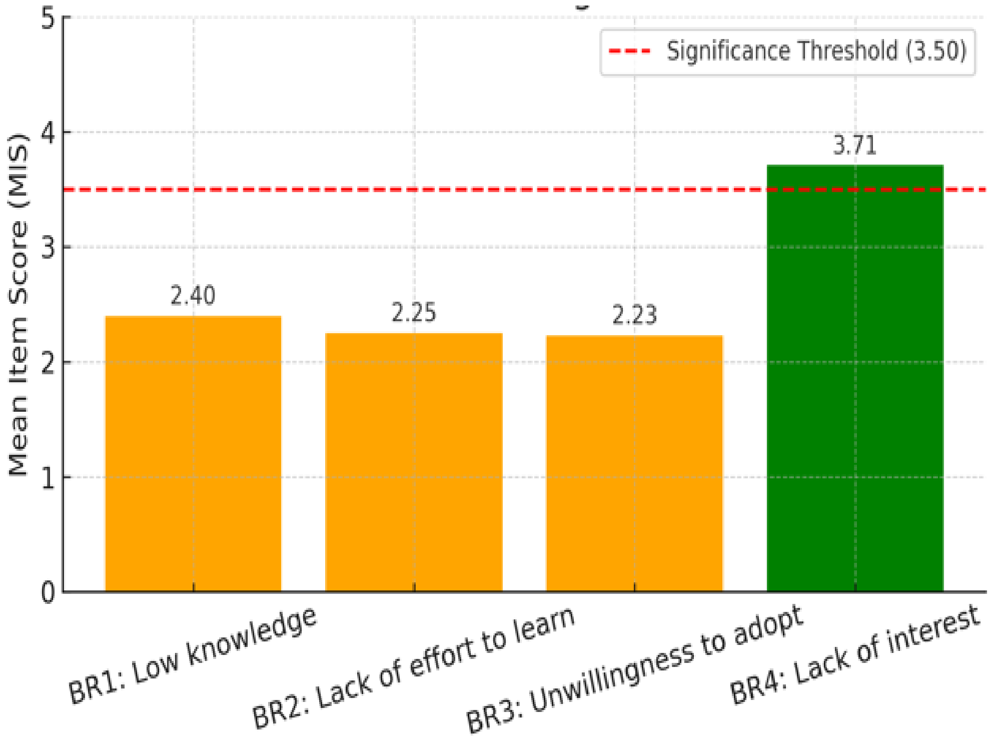

Figure 3: Mean Item Scores for Knowledge and Awareness Barriers

4.1 Respondents' Profile

A total of 52 valid responses were received. Table 2 summarizes the respondents' profile.

Table 2: Respondents' Profile

Category	Number	Percentage
Job Position		
Project/Construction Manager	9	17.3%
Civil Engineer	29	55.8%
Contractor	8	15.4%
Concrete Mixing Employee	6	11.5%
Academic Qualification		
Diploma	6	11.5%
Bachelor's Degree	28	53.8%
Master's Degree	17	32.7%
Doctorate	1	1.9%
Years of Experience		
Less than 5 years	20	38.5%
5–10 years	20	38.5%
10–15 years	7	13.5%
15–20 years	3	5.8%
More than 20 years	2	3.8%

4.2 Knowledge and Awareness Barriers

Table 3 presents result for knowledge and awareness barriers. Unexpectedly, three of four barriers were classified as slightly significant (MIS 2.23–2.40), indicating that professionals in Tobruk possess adequate knowledge, make efforts to learn, and are willing to adopt sustainable concrete. Only BR4 (lack of interest in sustainability) was classified as significant (MIS 3.71). Kruskal-Wallis results showed no significant differences between professional groups ($p > 0.05$).

Table 3: Knowledge and Awareness Barriers

Barrier ID	Description	MIS	Rank	Significance
BR1	Low knowledge about sustainable concrete	2.40	2	Slightly Significant
BR2	Lack of effort to learn	2.25	3	Slightly Significant
BR3	Unwillingness to adopt	2.23	4	Slightly Significant
BR4	Lack of interest in sustainability	3.71	1	Significant

4.3 Economic and Resource Barriers

Based on the analysis results of the four barriers categorized under the economy and resources category, participants rated them as being significant. The item scores, on the mean, were between 3.46 and 3.79, which shows that they had significant impacts on the adoption of sustainable concrete. Figure 4 presents the mean item scores for economic and resource barriers.

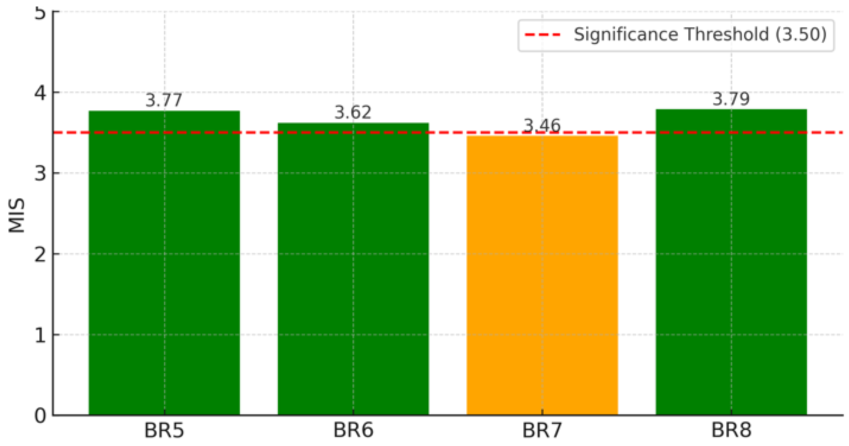

Figure 4: Mean item scores for economic and resource barriers.

All four economic and resource barriers were rated as significant (MIS 3.46–3.79). Lack of demand (BR8) was the highest-rated barrier (MIS 3.79), followed by high cost (BR5, MIS 3.77), limited availability (BR6, MIS 3.62), and uncertainty about quality (BR7, MIS 3.46). No statistically significant differences were found between professional groups ($p > 0.05$).

Table 4: Economic and Resource Barriers

Barrier ID	Description	MIS	Rank	Significance
BR5	High cost of materials	3.77	2	Significant
BR6	Limited availability	3.62	3	Significant
BR7	Uncertainty about quality	3.46	4	Averagely Significant
BR8	Lack of demand	3.79	1	Significant

4.4 Technical and Implementation Barriers

All technical barriers were rated as significant (MIS 3.54–3.79). Shortage of skilled labor (BR10) was the highest-rated barrier (MIS 3.79), followed by limited methods and tools (BR9, MIS 3.75), lack of technologies (BR11, MIS 3.56), and lack of professional designers (BR12, MIS 3.54). A statistically significant difference was found for BR10 ($p = 0.02$), with concrete company employees rating this barrier lower than other groups. No significant differences were found for other barriers ($p > 0.05$).

Table 5: Technical and Implementation Barriers

Barrier ID	Description	MIS	Rank	Significance
BR9	Limited methods and tools	3.75	2	Significant
BR10	Shortage of skilled labor	3.79	1	Significant
BR11	Lack of technologies	3.56	3	Significant
BR12	Lack of professional designers	3.54	4	Significant

Considering the participants assessment, it seems all of them were viewed these barriers as critical. The mean item scores (MIS) were between 3.54 and 3.79. The lacking skilled labor (BR10) was noted as the most significant barrier. Figure 5 shows the mean item scores for technical and implementation barriers.

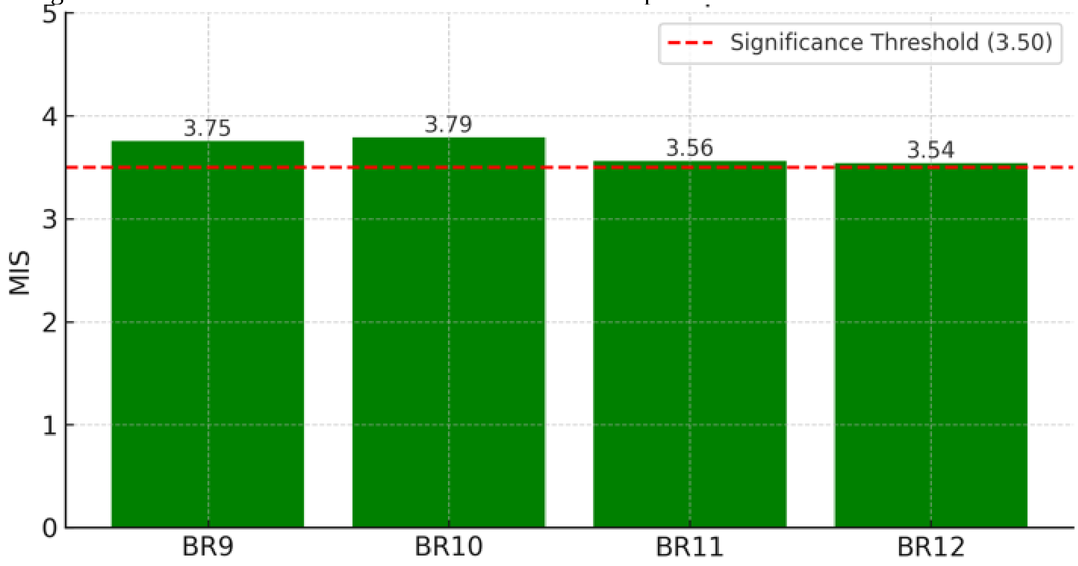

Figure 5: Mean Item Scores for Technical and Implementation Barriers**.**

4.5 Regulatory and Cultural Barriers

Regulatory and cultural barriers showed mixed results, with five barriers rated as significant (MIS 3.54–3.81) and two as averagely significant (MIS 3.23–3.46). Lack of demonstration projects (BR18) was the highest-rated barrier overall (MIS 3.81), followed by passive industry culture (BR15, MIS 3.79), misconceptions about cost (BR17, MIS 3.75), client resistance (BR14, MIS 3.71), and lack of sustainability criteria in bidding (BR16, MIS 3.54). No significant differences were found between professional groups ($p > 0.05$).

Table 6: Regulatory and Cultural Barriers

Barrier ID	Description	MIS	Rank	Significance
BR13	Absence of clear guidelines	3.46	6	Averagely Significant
BR14	Client resistance	3.71	4	Significant
BR15	Passive industry culture	3.79	2	Significant
BR16	No sustainability in bidding	3.54	5	Significant
BR17	Misconceptions about cost	3.75	3	Significant
BR18	Lack of demonstration projects	3.81	1	Significant
BR19	Lack of government support	3.23	7	Averagely Significant

4.6 Overall Ranking of Barriers

Table 7 presents the complete ranking of all 19 barriers in descending order of MIS.

Table 7: Overall Ranking of Barriers

Rank	Barrier ID	MIS	Category
1	BR18	3.81	Regulatory & Cultural
2	BR8	3.79	Economic & Resources
3	BR10	3.79	Technical & Implementation
4	BR15	3.79	Regulatory & Cultural
5	BR5	3.77	Economic & Resources
6	BR17	3.75	Regulatory & Cultural
7	BR9	3.75	Technical & Implementation
8	BR14	3.71	Regulatory & Cultural
9	BR4	3.71	Knowledge & Awareness
10	BR6	3.62	Economic & Resources
11	BR11	3.56	Technical & Implementation
12	BR12	3.54	Technical & Implementation
13	BR16	3.54	Regulatory & Cultural
14	BR7	3.46	Economic & Resources
15	BR13	3.46	Regulatory & Cultural
16	BR19	3.23	Regulatory & Cultural
17	BR1	2.40	Knowledge & Awareness
18	BR2	2.25	Knowledge & Awareness
19	BR3	2.23	Knowledge & Awareness

4.7 Summary of Results

Table 8 presents the key areas of concern and proposed solutions for promoting sustainable concrete practices.

Table 8: Proposed Solutions by Category

Main Area	Proposed Solutions
Awareness and Education	Increase education on sustainability benefits; incorporate sustainability in university curricula
Financial Incentives	Offer tax breaks, loans, and purchase reductions to promote sustainable materials
Material Quality and Supply	Establish quality assurance offices; collaborate with universities
Technology and Equipment	Provide advanced equipment; establish local workshops
Workforce Development	Develop skill programs through university-company partnerships
Research and Development	Fund R&D centers; support innovation projects
Guidelines and Standards	Implement national sustainable construction standards
Client Awareness	Initiate educational programs and promotional campaigns
Industry Culture Shift	Rewards for organizations implementing sustainable practices
Procurement Practices	Integrate sustainability criteria in bidding; finance model projects

5. Discussion

5.1 Knowledge and Awareness Barriers

The finding that knowledge and awareness barriers were not critical (MIS 2.23–3.71) is notable and contrasts with many studies in developing countries. While Osuizugbo et al. (2020) and Ifije and Aigbavboa (2020) identified these as significant barriers in Nigeria, this study reveals that professionals in Tobruk possess relatively high awareness, make efforts to learn, and demonstrate willingness to adopt sustainable concrete. This is likely attributable to the high level of education among respondents (53.8% held bachelor's degrees, 32.7% held master's degrees), consistent with findings in Kuwait (AlSanad, 2015).

However, the significant rating for BR4 (lack of interest in sustainability, MIS = 3.71) is concerning. This finding aligns with Awaili, Uzunoglu and Özden (2020), who reported that 55% of Libyan respondents identified lack of interest in green development as a major barrier. This suggests that while individual professionals are knowledgeable and willing, systemic barriers prevent collective action, as also noted by Khalil, Rathnasinghe and Kulatunga (2021). The Kruskal-Wallis results ($p > 0.05$) confirming broad agreement across professional groups further support this interpretation.

5.2 Economic and Resource Barriers

The significant ratings for economic barriers (MIS 3.46–3.79) align with global findings. Nilimaa (2023) identified higher initial costs as a primary barrier, particularly for small projects with limited budgets. The 1–25% cost premium for sustainable materials reported by Davies and Davies (2017) represents a substantial challenge in Tobruk's price-sensitive construction market. This is compounded by limited material availability (BR6, MIS = 3.62), which is prevalent in developing countries with underdeveloped supply chains (Jaradat et al., 2024).

The lack of demand (BR8, MIS = 3.79) emerges from two interconnected factors: (1) uncertainty about material quality and performance (BR7, MIS = 3.46), as noted by Ahmed et al. (2023), and (2) the perceived high cost and limited availability of these materials (Badraddin et al., 2021). This creates a vicious cycle where limited availability increases costs, reducing demand, which in turn limits supplier investment in sustainable materials. Breaking this cycle requires coordinated intervention addressing multiple barriers simultaneously, such as establishing quality assurance programs and providing financial incentives (Onososen, Osanyin and Adeyemo, 2019).

5.3 Technical and Implementation Barriers

The significance of all four technical barriers (MIS 3.54–3.79) aligns with research from other developing countries. Aghimien et al. (2018) identified lack of skilled labor as a major constraint in Zambia, while Zulu et al. (2023) noted the absence of sustainable construction technologies as a critical factor. The shortage of professional designers (BR12, MIS = 3.54) is particularly concerning because it suggests a systemic failure in higher education and professional development (Zollo et al., 2023).

The statistically significant difference for BR10 (shortage of skilled labor) is noteworthy. The lower rating by concrete company employees suggests this barrier may be less critical for material suppliers than for practitioners who directly handle these materials. This finding indicates that intervention strategies should target the construction site level, where implementation bottlenecks are most acute.

5.4 Regulatory and Cultural Barriers

The high ratings for regulatory and cultural barriers (MIS 3.23–3.81) confirm that institutional and behavioral factors are central to the slow adoption of sustainable concrete. The lack of demonstration projects (BR18, MIS = 3.81) is particularly important because demonstration projects serve multiple functions: they prove technical viability, reduce perceived risk, and provide economic cost-benefit evidence (Aghimien et al., 2018; Khalil, Rathnasinghe and Kulatunga, 2021).

The passive industry culture (BR15, MIS = 3.79) and absence of sustainability in bidding (BR16, MIS = 3.54) reflect a systemic problem where sustainability is not valued or required in project procurement (Durdyev et al., 2018). This is compounded by client resistance and cost misconceptions (BR14 and BR17), as previously documented by Onososen, Osanyin and Adeyemo (2019) and Ifije and Aigbavboa (2020). The final piece is the lack of government support (BR19, MIS = 3.23) and clear guidelines (BR13, MIS = 3.46), which, while rated lower than other barriers, represent foundational institutional obstacles (Badraddin et al., 2021; AlSanad, 2015). Without government mandates, financial incentives, and clear policy frameworks, individual efforts remain insufficient to drive widespread adoption.

6. Conclusion

This thesis aimed to identify and assess the critical barriers to sustainable concrete adoption in Tobruk, Libya, and propose strategic solutions to overcome these obstacles. Nineteen barriers were identified and classified into four categories based on a comprehensive literature review. The study employed a quantitative methodology, collecting 52 valid questionnaire responses from construction professionals, including civil engineers, project managers, contractors, and concrete industry employees. The findings revealed that:

1. **Knowledge and awareness barriers were not critical** (MIS 2.23–3.71), except for lack of interest in sustainability (BR4, MIS 3.71). This finding contrasts with many studies in developing countries, reflecting the relatively high level of education among professionals in Tobruk.
2. **Economic and resource barriers were consistently significant** (MIS 3.46–3.79), with lack of demand (BR8), high cost (BR5), and limited availability (BR6) being the most critical obstacles. These findings align with global research in similar contexts.
3. **Technical and implementation barriers were all rated as significant** (MIS 3.54–3.79), with shortage of skilled labor (BR10) emerging as the most critical barrier. The lack of tools, methods, technologies, and professional designers collectively hinders implementation.
4. **Regulatory and cultural barriers showed mixed results**, with five barriers rated as significant (MIS 3.54–3.81) and two as averagely significant (MIS 3.23–3.46). The most critical barriers were lack of demonstration projects (BR18), passive industry culture (BR15), and misconceptions about cost (BR17).
5. **The overall ranking** of 19 barriers revealed that the top five most critical barriers were: lack of demonstration projects (BR18, 3.81), lack of demand (BR8, 3.79), shortage of skilled labor (BR10, 3.79), passive industry culture (BR15, 3.79), and high cost (BR5, 3.77).

Based on these findings, strategic solutions were developed across four categories: (1) awareness and education, (2) economic and resources, (3) technical and implementation, and (4) regulatory and cultural. These solutions include establishing government funding programs and financial incentives, developing workforce skills and professional training programs, increasing research and development funding, implementing national sustainable construction standards and guidelines, and creating demonstration projects.

This research contributes significantly to the limited body of knowledge on sustainable concrete adoption in Libya and North Africa. It provides evidence-based insights for policymakers and stakeholders in similar developing contexts. Future research should extend this methodology to other Libyan cities, apply broader sustainable construction approaches, and evaluate the effectiveness of the proposed solutions.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

7. References

Abdausamea, A., Saaed, S. A. A. and Ali, A. (2018) 'Towards Sustainable Building in Libya', *Al-Mukhtar Journal of Engineering Research*, 1(2), pp. 31-36.

Aghimien, D., Aigbavboa, C., Oke, A. and Musenga, C. (2018) 'Barriers to sustainable construction practices in the Zambian construction industry', in *Proceedings of the International Conference on Industrial Engineering and Operations Management*, Paris, France, July 26-27, pp. 2383-2392.

Ahmed, A. M., Sayed, W., Asran, A. and Nosier, I. (2023) 'Identifying barriers to the implementation and development of sustainable construction', *International Journal of Construction Management*, 23(8), pp. 1277-1288.

AlSanad, S. (2015) 'Awareness, drivers, actions, and barriers of sustainable construction in Kuwait', *Procedia Engineering*, 118, pp. 969-983.

Askar, M. K., Al-Kamaki, Y. S. and Hassan, A. (2023) 'Utilizing polyethylene terephthalate PET in concrete: a review', *Polymers*, 15(15), p. 3320.

Assi, L., Carter, K., Deaver, E. E., Anay, R. and Ziehl, P. (2018) 'Sustainable concrete: Building a greener future', *Journal of Cleaner Production*, 198, pp. 1641-1651.

Awaili, A. M. E., Uzunoglu, S. S. and Özden, Ö. (2020) 'The analysis of barriers in green building development in Libya', *Architecture*, 6, pp. 30-40.

Badraddin, A. K., Rahman, R. A., Almutairi, S. and Esa, M. (2021) 'Main challenges to concrete recycling in practice', *Sustainability*, 13(19), p. 11077.

Davies, O. and Davies, I. (2017) 'Barriers to implementation of sustainable construction techniques', *MAYFEB Journal of Environmental Science*, 2.

Durdyev, S., Zavadskas, E. K., Thurnell, D., Baniotopoulos, C. and Ihtiyar, A. (2018) 'Sustainable construction industry in Cambodia: Awareness, drivers and barriers', *Sustainability*, 10(2), p. 392.

Hashmi, A. F., Shariq, M., Baqi, A. and Akhtar, S. (2022) 'Evaluation of eco-friendly concrete having waste PET as fine aggregates', *Cleaner Materials*, 2, p. 100026.

Ifije, O. and Aigbavboa, C. (2020) 'Identifying barriers of sustainable construction: A Nigerian case study', in *MATEC Web of Conferences*, 312, p. 04004.

Jaradat, A., Sweis, G., Abu-Khader, W. and Sweis, R. (2024) 'Green building, carbon emission, and environmental sustainability of construction industry in Jordan: Awareness, actions and barriers', *Ain Shams Engineering Journal*, 15(2), p. 102441.
Khalil, A., Rathnasinghe, A. P. and Kulatunga, U. (2021) 'Challenges for the implementation of sustainable construction practices in Libya', *Construction Economics and Building*, 21(3), pp. 243-261.
Liew, K. M., Sojobi, A. O. and Zhang, L. W. (2017) 'Green concrete: Prospects and challenges', *Construction and Building Materials*, 156, pp. 1063-1095.
Lima, L., Trindade, E., Alencar, L., Alencar, M. and Silva, L. (2021) 'Sustainability in the construction industry: A systematic review of the literature', *Journal of Cleaner Production*, 289, p. 125730.
Mehta, A. and Ashish, D. K. (2020) 'Silica fume and waste glass in cement concrete production: A review', *Journal of Building Engineering*, 29, p. 100888.
Nilimaa, J. (2023) 'Smart materials and technologies for sustainable concrete construction', *Developments in the Built Environment*, 15, p. 100177.
Onososen, A. O., Osanyin, O. and Adeyemo, M. O. (2019) 'Drivers and barriers to the implementation of green building development', *PM World Journal*, 8(9), pp. 1-15.
Osuizugbo, I. C., Oyeyipo, O., Lahamni, A., Morakinyo, A. and Olaniyi, O. (2020) 'Barriers to the adoption of sustainable construction', *European Journal of Sustainable Development*, 9(2), p. 150.
Tamanna, N., Tuladhar, R. and Sivakugan, N. (2020) 'Performance of recycled waste glass sand as partial replacement of sand in concrete', *Construction and Building Materials*, 239, p. 117804.
Xiao, J., Ma, Z., Sui, T., Akbarnezhad, A. and Duan, Z. (2018) 'Mechanical properties of concrete mixed with recycled powder produced from construction and demolition waste', *Journal of Cleaner Production*, 188, pp. 720-731.
Zollo, J., Zulu, S. L., Zulu, E., Chabala, M. and Chunda, N. (2023) 'Drivers and barriers to sustainability practices in the Zambian Construction Industry', *International Journal of Construction Management*, 23(12), pp. 2116-2125.

