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Assessment of the Adoption of Sustainable Design in Concrete Structures: A Survey of Structural Engineers

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تقييم تبني التصميم المستدام في المنشآت الخرسانية: دراسة استقصائية لمهندسي الإنشاءات

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Abstract:
This study was conducted to evaluate the adoption of sustainable design in reinforced concrete structures through a field survey of civil engineers. The study relied on an electronic questionnaire to measure a set of environmental and construction indicators, such as the use of alternative materials, the reduction of carbon emissions, and construction waste management in compliance with sustainability standards. The collected data were statistically analyzed using descriptive and analytical methods to interpret responses and explain the extent to which sustainable design principles are applied in concrete construction projects.
The results showed a strong awareness of the importance of sustainable design and the use of alternative materials; however, the practical application of these concepts remains limited. It was also found that attention to carbon emission reduction and waste management is at a moderate level and requires further improvement.
The study recommends strengthening the accurate implementation of sustainability concepts and integrating them into construction practices; promoting environmental awareness among civil engineers; improving waste management systems and enhancing recycling practices; encouraging the use of alternative materials through policies and guidelines; and adopting sustainability assessment systems to ensure the effective implementation of sustainability within the construction sector.

Keywords: Sustainable design, reinforced concrete structures, structural engineers, alternative materials, environmental sustainability.

الملخص
أجريت هذه الدراسة لتقييم مدى تبني التصميم المستدام في الهياكل الخرسانية من خلال دراسة ميدانية لمهندسي الإنشاءات ، حيث اعتمدت على استبانة إلكترونية لقياس مجموعة من المؤشرات البيئية والإنشائية مثل استخدام المواد البديلة وتقليل انبعاثات ثاني أكسيد الكربون وإدارة مخلفات البناء وفقاً لمعايير الاستدامة. تم تحليل البيانات المجمعة إحصائياً باستخدام الطرق الوصفية والتحليلية لتفسير الاستجابات وتوضيح مدى تطبيق مبادئ التصميم المستدام في مشاريع الإنشاء الخرسانية.
أظهرت النتائج وجود وعي كبير بأهمية التصميم المستدام واستخدام المواد البديلة إلا أن التطبيق العملي لهذه المفاهيم لا يزال محدوداً . كما تبين أن الأهتمام بتقليل انبعاثات الكربون وإدارة المخلفات يقع في مستوى متوسط ويحتاج إلي مزيد من التحسين.

توصي الدراسة بتعزيز التطبيق الدقيق لمفاهيم الاستدامة ودمجها في الممارسات الإنشائية ونشر الوعي البيئي بين مهندسي الإنشاءات وتحسين أنظمة إدارة المخلفات وتعزيز ممارسات إعادة التدوير وتشجيع استخدام المواد البديلة من خلال السياسات والإرشادات واعتماد أنظمة تقييم الاستدامة لضمان التطبيق الفعال لمبادئ الاستدامة في قطاع التشيد.

الكلمات المفتاحية: التصميم المستدام ، الهياكل الخرسانية، مهندسو الإنشاءات، المواد البديلة، الاستدامة البيئية.

1-General Framework of the Study

1.1Introduction

The construction industry, including reinforced concrete structures, is regarded as one of the largest industry sectors in the context of global consumption of natural resources as well as greenhouse gas emissions [1].' Therefore, sustainable design has become an urgent necessity to balance economic and social development requirements and environmental protection for future generations [2].' Sustainable design in concrete structures entails the use of environmentally friendly materials, minimization of energy consumption during the building life cycle, and enhanced resource efficiency aimed at reducing the carbon footprint of construction projects [3].'

Despite the significance of sustainable design, there are various barriers to its adoption in the concrete structures sector, including lack of awareness, limited legislation that supports sustainable designs, high initial cost of sustainable designs, and lack of relevant sustainable design expertise among structural engineers [4,5].' There is an urgent need to understand the factors that influence structural engineers' decisions regarding the adoption of sustainable design practices and the challenges they face, according to recent studies [6].'

Even though the interest in sustainable design has been on the rise, most of the previous studies focused on the theoretical aspects or modern technologies without analyzing the actual implementation of sustainable design among structural engineers. In addition, studies related to reinforced concrete structures have not provided a field-based assessment of the level of adoption of sustainability principles in construction practices nor has it provided a clear understanding of the challenges faced by engineers in the case of practical implementation.

From the perspective, this study is conducted to provide a realistic field view on the levels of adoption of sustainable design in reinforced concrete structures based on the general opinion of structural engineers. This helps in establishing the main challenges and barriers that hinder the application of sustainability principles in construction works.

The study is descriptive-analytical in approach, where a specialized questionnaire was created and delivered to samples of (60) structural engineers experienced in design and construction of reinforced concrete structural buildings. The aim was to collect both quantitative and qualitative data concerning the reality of sustainable design adoption. The data are analysed through statistical methods to interpret patterns of response and draw findings.

In this context, experimental results showed that structural engineers have a surprising level of recognition of the importance of sustainable design in reinforced concrete systems, especially in terms of opportunity material use and carbon abatement It holds. The results also showed a certain interest in waste and carbon reduction, which suggests an opening between theoretical knowledge and rational utility On the other hand, the findings confirmed a high quality process to enhance structural design performance and reduce fabric consumption without compromising the structural safety risk increase structural safety.

Accordingly, the gaze emphasizes the need to rework theoretical awareness into effective practical software by strengthening supporting regulations, providing specialized training programs for engineers, and developing clear policies for using sustainable materials to enhance the environmental transformation performance of the contribution

1.2 Research Problem

From the perspective of structural engineers, the research problem is that there is no comprehensive systematic understanding of the level of adoption of sustainable design practices in reinforced concrete structures. This gap is clearly exhibited by failure to identifying the key factors that influence engineering decision making, whether drivers that encourage environmental innovation or barriers that hinder its implementation. Therefore, there is a need for a survey study that provides insight into the reality of sustainable design in reinforced concrete structures from the perspective of structural engineers and determines the level of adoption and key challenges.

The primary research question for the study is: To what extent do structural engineers adopt sustainable design principles in reinforced concrete structures, and what constraints predominantly affect their application in engineering practice?

1-3 Objectives of the Study

This study aims at assessing the level of adoption of sustainable design practice in reinforced concrete structural from the perspective of structural engineers. In addition, the study seeks to scientifically recommend what to do to boost sustainable design implementation in the reinforced concrete sector adopting survey results.

1-4 Significance of the Study

The significance of this study is highlighted in the following points:

1-It is meant to help bridge the knowledge gap by giving insights into the sustainable design adopted by structural engineers and the factors that affect their decisions.

2-The study findings offer policymakers, legislators, and academic institutions valuable data in making effective policies and regulations that foster the uptake of sustainable construction practices.

3-It leads to the formulation of strategies that encourage the use of more sustainable materials, and less energy and carbon emissions in reinforced concrete projects.

4-It helps identify weaknesses in knowledge and expertise structural engineers have, which allows the development of relevant training programs targeted at enhancing their expertise in sustainable design.

1-5 Previous Studies

Recent studies addressed sustainability within the field of creation and reinforced concrete structures from more than one perspective, with regulations, technologies, installation options, and implementation limits [7] aimed to develop advice for low-carbon concrete procurement authorities to incorporate carbon reduction guidelines the field of creation. The have a look to determine that directing public procurement near substances with low emissions and utilizing performance-based absolute requirements and carbon emission standards are various simplest tools to reduce the similar carbon footprint and enhance sustainability within the manufacturing industry**.**
In terms of implementation barriers [4] identified and evaluated the main barriers that hinder the implementation of sustainable construction projects. Their impact confirmed that sensitive policies, lack of knowledge of modern technologies, and financial constraints are the biggest constraints to adopting sustainability This is consistent with (al-Otaibi et al.,2024[8]), who focused on untested concrete and found that technical and operational challenges remain fundamental constraints, while social norms and institutional norms are not sufficient barriers, emphasizing the importance of institutional support in advancing customer adoption .From a technical angle(Habibi et al., 2024[9]) proved that 3D concrete printing contributes to reducing textile consumption and manufacturing waste while increasing performance; However, its broad application remains limited due to technical challenges and the need for standardized approaches. Similarly [2] highlighted that low-carbon concrete technologies can significantly reduce carbon emissions; But their implementation is constrained through regulatory constraints and market conditions.

In the same context(the Global Cement and Concrete Association [10] reported significant progress in the cement and concrete industry toward achieving net-zero carbon emissions through the adoption of alternative fuels, supplementary cementitious materials, and carbon capture technologies. However, achieving long-term sustainability goals requires stronger regulatory support and broader adoption of low-carbon solutions, emphasizing the need for systemic transformation. From a design perspective [11] emphasized that early-stage design decisions play a crucial role in determining embodied carbon levels in structural systems, where selecting optimal design alternatives in the initial phases significantly contributes to higher efficiency and sustainability performance.

Overall, the reviewed literature shows that although previous studies have explored sustainability from technological, regulatory, and design perspectives, they are largely focused on industry-level or technical aspects. There remains a clear gap in understanding the extent to which structural engineers themselves adopt sustainable design practices in real-world applications, as well as the factors influencing their decision-making and actual implementation levels. This gap is addressed in the present study, which evaluates the adoption of sustainable design in reinforced concrete structures through a survey-based investigation of structural engineers.

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2. Theoretical Framework of the study

2.1 Concept of Sustainable Design

Sustainable design is a philosophy and an approach of designing products, structures, and systems that do not undermine the ability of future generations to meet their own needs [4].’ This concept goes beyond aesthetic and functional considerations to include environmental, economic and social dimensions of a project from the initial design stage to the end of the building life cycle [1].’ Sustainable design has several dimensions, which are:

2.1.1 Environmental Dimension: The environmental dimension seeks to reduce the ill effects of projects on the environment. They include efficient use of resources, reduction of wastes, reduction of carbon emissions, and protection of biodiversity [9].’ In the context of concrete structures, this means choosing low-carbon materials like green concrete, recycled aggregates, and enhancing energy efficiency in manufacturing and construction processes [2].’

2.1.2Economic Dimension: The economic dimension emphasizes on realize long-term economic viability of sustainable projects, taking into account the initial costs, operational costs, and costs of maintenance [3].' Sustainable design can also help save on energy and water consumption and save on service life of buildings to enhance returns on investment [6].'

2.1.3Social Dimension: The social sustainability aspect deals with promoting the quality of life to the users as well as the neighbourhoods through provision of healthy and safe environments, social equity and community participation [4].' In a concrete structure, this may be reflected in enhanced indoor air quality, enhanced natural lighting, and noise reduction.

2.2Principles of Sustainability in Concrete

Concrete is by far the world's most used construction material which means that it is very important to apply sustainability in its production and use we are to achieve the sustainable development goals which include environmental protection, economic stability and social progress in the construction field [1].' Also we see that the main sustainability in concrete is put forth by reducing the carbon footprint which we do by way of reducing cement emissions and use of low carbon alternatives and also by way of using supplementary materials, in also improving resource efficiency which we do through the use of recycled aggregates and industrial by products, we also see that we improve durability thus reducing maintenance needs, we apply life cycle assessment (LCA) which we use to study environmental impact at all stages, we go for optimized design which in turn minimizes material use yet at the same time we maintain performance, and we promote the recycling and reusing of concrete at the end of its life cycle [3,7,8,9,12,13,14,15].' These basic principles will go on to guide in the development of future sustainable practices in concrete and will help structural engineers today in the design of structures that put us on a path to a more environment and socially sustainable future.

2-3Alternative Materials in Sustainable Concrete

Alternative materials are one of the pillars to achieve sustainability in the concrete industry. Replacing the traditional raw materials with alternative ones reduces environmental impact by utilizing raw materials and industrial by-products that would be otherwise dumped on environment turning them into products of significant value [4].'

Among the main types of alternative materials are:

2.3.1 Supplementary Cementitious Materials (SCMs)

Supplementary cementitious materials (SCMs) are widely used to replace concrete Portland cement, reducing the carbon emissions associated with the production of cement, and include materials that include fly ash, ground granular blast furnace slag (GGBFS), silica fume, and so on. There are also herbal or heat-treated pozzolans, all of which enhance solid performance and enhance shelf life [12,13].' Fly ash derived from coal electrical blooms improves workability, power, and strength and reduces shrinkage cracking, while GGBFS, commercially derived from iron and metal fabrication, complements resistance to chemical attacks and long-term strength, and silica fume from silica metal as a resistant fuel [13].' Furthermore, calcined kaolin and rice husk ash with herbal and thermally treated pozzolans offer sustainable alternatives to cement replacement that further promote the environmental performance of the concrete [12].'

2.3.2 Alternative Aggregate Materials

Alternative sand materials play an important role in sustainable concrete construction through the replacement of herbal aggregates, which represent approximately 60–70% of the concrete volume, to reduce the depletion of herbal sources and landfill waste [14].'in the alternative aggregates that can be manufactured from. coarse fine aggregates in fresh concrete, which provide mechanical properties similar to herbal aggregate when used in good replacement layers and contribute to better durable concrete [7,16].' Furthermore, used casting sand from metal casting processes can partially or completely replace natural sand, help reduce environmental pollution, and improve certain concrete housings [9].' Recycled glass waste can also be used as composite or Pozzo crepe, the achievement of demolition products, which include bricks and tiles, can be crushed and reused as aggregate to make new concrete (International Finance Corporation [17].' Together, these opportunities contribute to the transition to a circular finance system in the construction industry through enhanced environmental and economic sustainability performance.

2-4Carbon Emissions of Concrete

Concrete is the most widely used construction fabric worldwide, and cement and concrete produce about 7% to 8% of the world's carbon emissions, raising huge issues due to the contribution of rising temperatures worldwide (Global Cement and Concrete Association [10].' transform, causing a large amount of carbon dioxide to be released [18].'The calcination process contributes approximately 50% to 60% of the total emissions from cement blooms, as calcium carbonate is thermally decomposed into calcium oxide, releasing carbon dioxide as a by-product [19]' Furthermore, the gas combustion required to reach fuel was about 14—30% 40% of normal emissions are borrowed money (International Energy Agency [20].’The emissions also contain equivalent hydrocarbons due to the extraction and processing of uncooked materials, transportation, manufacturing and on-site manufacturing processes Traditional concrete is expected to vary between 240 and 320 kg of carbon dioxide equivalent to cubic meters of carbon equivalent (Green Building Circuit Council [21].’Recent studies specialize in reducing these environmental impacts by partial replacement of clinker with filler cementitious materials, use of opportunity fuels, implementation of carbon capture and storage technologies In addition, optimization of structural design can reduce the amount of concrete used without compromising safety[2].’

2-5Sustainability Standards in Concrete Structures

Sustainability standards represent a systematic tool for evaluating the compliance of construction projects with environmental, economic, and social requirements [22].’ In recent years, there has been a significant development in integrating specific green concrete criteria within global rating systems [23].’

2.5.1Main Global Rating Systems

2.5.1.1Leadership in Energy and Environmental Design (LEED): LEED is one of the most widely used certification systems. It awards points for concrete that incorporates recycled materials (such as recycled aggregates) or supplementary cementitious materials that reduce embodied carbon [24].’

2.5.1.2 Building Research establishment environmental Assessment Method (BREEAM): This system adopts a holistic life cycle approach, assessing the environmental impact of concrete from raw material extraction to end-of-life [25].’ It also promotes the use of high-performance and durable concrete to extend service life [26].’

2.5.1.3Concrete Sustainability Council (CSC): These standards are specifically designed for the cement and concrete sector, evaluating plants and supply chains based on Environmental, Social, and Governance (ESG) criteria [27].’ They aim to enhance transparency in the production of green concrete [28].’

2.5.2 Technical Standards for Evaluating Sustainable Concrete

2.5.2.1 Life Cycle Assessment (LCA):

2.5.2.1 Life Cycle Assessment (LCA): LCA is used to measure general environmental impact, which includes global warming potential, resource consumption, and water consumption [29].’

2.5.2.2 Embedded Carbon Index: This indicator measures the amount of carbon dioxide emitted equivalent to cubic meters of concrete and is considered an important metric in modern construction efforts [13].’

2.5.2. three durability and lifetime standard: This overarching goal is to reduce the need for maintenance and replacement by extending the structural life of concrete, thus protecting resources over time [30].’

2.5.2.4 resource efficiency standards: This includes the proportion of recycled materials and field-produced materials used within the concrete mix design [31].’

These requirements additionally manually structural engineers towards making layout decisions that support the transition to environmentally sustainable building practices.

2-6Construction and Demolition Waste Management

Construction and demolition (C&D) waste management is considered a fundamental pillar in achieving a circular economy within the construction sector, as these wastes account for approximately 30% to 40% of total global solid waste generation [32].’ Recent studies have focused on developing strategies aimed at reducing reliance on landfills and maximizing the recovery and reuse of consumed materials (United States Environmental Protection Agency [33].’

2.6.1 Modern Waste Management Strategies

Waste reduction in construction begins at the design stage through adopting on-site construction techniques and design-for-deconstruction principles to minimize material waste [34]' followed by the reuse of structural elements such as beams and columns from demolished buildings without full reprocessing to save energy and reduce emissions [35], while recycling involves crushing concrete to produce recycled aggregates, where studies show that using up to 30% recycled aggregate does not significantly affect concrete strength and helps reduce environmental impacts [31,36].’

2.6.2 Environmental and Economic Impacts of Waste Management

Recycling in construction reduces the carbon footprint by lowering emissions from raw material extraction and transport, conserves natural resources by limiting the need for new quarries and protecting ecosystems, and provides economic benefits through reduced landfill costs and cheaper materials, thereby promoting sustainable design practices among engineers and contractors while reinforcing the environmental and economic role of waste management in modern structural engineering [37,38,39].’

2.7Structural Design Efficiency

Structural design efficiency is considered one of the most important pillars for reducing the environmental impact of buildings, as intelligent design can reduce the quantities of concrete and reinforcement steel by approximately 20% to 30% without compromising structural safety [11].’ In recent years, research has increasingly focused on integrating optimization algorithms into the early design stages [40].’

2.7.1Strategies for Improving Structural Efficiency

Strategies for improving structural efficiency involve topological optimization to distribute materials along stress flow paths and eliminate inefficient zones, performance-based design to achieve targeted structural and environmental objectives such as reducing embodied carbon per unit load, and the integration of BIM and AI to analyse numerous design alternatives and accurately estimate environmental impacts during the design stage [3,41,42,43].'

2.7.1Impact of Design Efficiency on Sustainability

Reducing concrete volume lowers embodied carbon emissions, optimized structural design minimizes material consumption and conserves resources, and lighter structural systems improve construction speed while reducing energy use on site [43,44].'

Structural design efficiency is a shared responsibility between structural and architectural engineers, requiring collaboration to achieve a balance between architectural aesthetics and engineering sustainability.

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3. Practical Framework of the Study (Research Methodology)

This study uses a descriptive and analytical approach to assess the degree of application of sustainable design in reinforced concrete structures from the perspective of structural engineers A comprehensive framework was developed to include the collection of quantitative records and statistical analysis to achieve this objective observation.

3.1. Population and Sample of the Study

3.1.1 Study Population

The studied population includes structural engineers working in consulting offices and creation firms.

3.1.2 Study Sample

A simple random sample made for a selected that may be representative of different engineering reports and activity levels. The sample consisted of 60 structural engineers.

The observational model proved to be selected with a limited length due to the peculiar nature of the population and its association with a specific group of engineers and experts working in the design and construction of reinforced concrete systems. Furthermore, the vast number of members to access has been limited to the period allocated for statistical collection. Also, look out for direct enjoyment and ownership of information related to sustainable design and reliable judgment about your people, which contributes to improving accuracy and reliability of answers and describes completely nothing of limited pattern size by looking at goals.

3.2 Study Material (Questionnaire)

3.2.1 Questionnaire Design

The researcher created an initial version of the questionnaire items by reviewing several clinical references and previous research related to the study topic in recent times The questionnaire is mainly developed based on the findings from the theoretical framework have a look at. In designing the questionnaire, the researcher considered the readability of the statements and their ease of answering.

3.2.2 Validity and Reliability Tests

To ensure validity and appropriate questionnaire size, the researcher conducted the following checks:

3.2.2.1 Content Validity

The researcher addressed the issue of content material validity within the questionnaire by ensuring that the questions covered in each form covered all dimensions of harassment examined as well as all aspects of the theoretical framework of the study.

3.2.2.2 Face Validity

Statistical analysis of the questionnaire items is conducted to ensure that the questionnaire items achieve the goals for which they were designed, i.e. The questionnaire included seven main sections aimed at comparing the amount of adoption of sustainable design standards in reinforced concrete structures, as follows.

1- Section One: General and demographic information of the participants.
2- Section Two: Use of alternative materials in sustainable concrete.
3- Section Three: Reduction of carbon emissions in reinforced concrete structures.
4- Section Four: Application of sustainability standards in construction projects.
5- Section Five: Waste management and recycling.
6- Section Six: Design efficiency and long-term sustainability.
7- Section Seven**:** Challenges and recommendations

3.2.2.3 Cronbach's Alpha Test for Validity and Reliability

Cronbach's alpha test, which is one of the crucial statistical tests used for questionnaire statistical analysis, is considered. So before doing statistical evaluation, it is very important to look at Cronbach's Alpha. This statistical test determines whether the questionnaire-based smartphone is entirely dependent on having an eye for patterns in the responses. The better the value of Cronbach's alpha coefficient, especially when it exceeds (0.60), the higher the internal consistency within the responses This indicates that the responses can be relied upon to achieve the purpose of the study and read its impact, which will further increase the confidence in the findings from the study.

3.3 Statistical Methods

Data could be analysed using the Statistical Package for the Social Sciences (SPSS). The following statistical techniques can be used:

3.3.1 Descriptive statistics

These include frequencies, percentages, calculation methods, wide variances, relative distributions, tables and graphs.

3.3.2 Inferential statistics

A t-test can be used to be aware of the large variation between engineers' reviews based primarily on observational variables.

This technology contributes to providing a contemporary country with a practical and thorough description of sustainable design practices in the field of engineering.

3.4Data Analysis and Study Tests

3.4.1 Reliability and Validity Test

To ensure the reliability and validity of the "study instrument," Cronbach's Alpha coefficient was calculated, in addition to the self-validity coefficient, which was obtained by calculating the square root of Cronbach's Alpha coefficient for the section that included questions answered according to a five-point rating scale ranging from (1) to (5). This section consisted of six statements in the questionnaire form. The results are presented in Table 1.

Table 1: Reliability and Validity Test Results

SN.	Section	Number of Items	Cronbach's Alpha (α)
1	Questionnaire Items	6	0.984

From the previous table, it can be observed that the Cronbach's Alpha coefficient (0.984) for the questionnaire is very high and exceeds the acceptable threshold of (0.60). This indicates a very high level of internal consistency in the responses.

3.4.2 Demographic Data:

3.4.2.1 Gender

Table 2: Frequency and Percentage Distribution of the Study Sample by Gender

Gender	Frequency	Percentage (%)
Male	52	87%
Female	8	13%
Total	60	100%

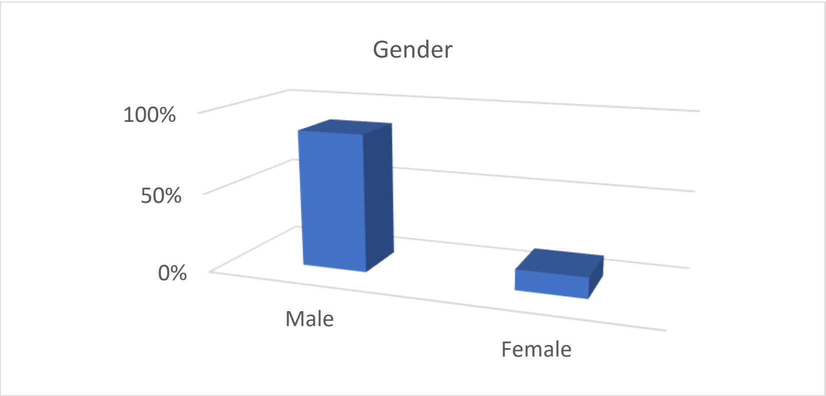

Figure 1: Percentage Distribution of the Study Sample According to Gender.

The data indicate a clear dominance of males in the sample compared to a limited representation of females this reflects the nature of the field or work environment, which is predominantly male-oriented; consequently, this may affect the diversity of perspectives presented in the study.

3.4.2.2 Educational Qualification

Table 3: Frequency and Percentage Distribution of the Study Sample by Educational Qualification

Educational Qualification	Frequency	Percentage (%)
PhD	7	11.6%
Master's Degree	25	41.7%
Bachelor's Degree	28	46.7%
Total	60	100%

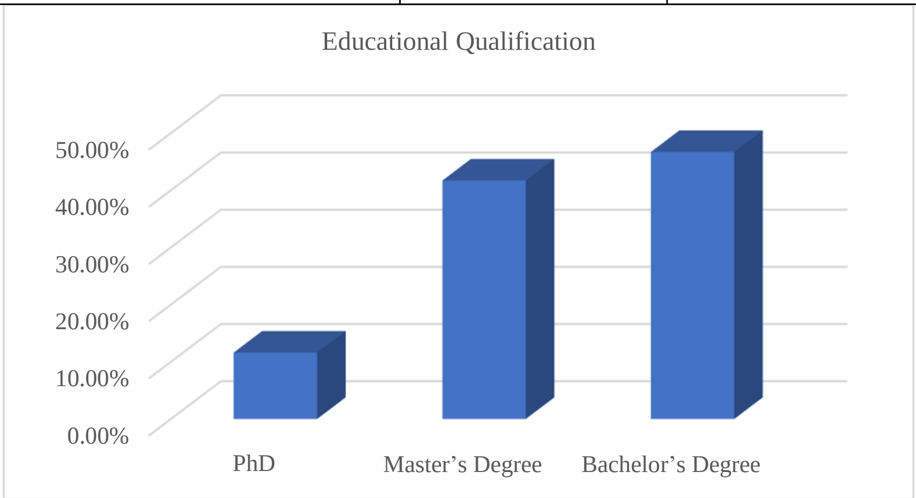

Figure 2: Percentage Distribution of the Study Sample According to Educational Qualification.

The results show that most of the sample participants hold Bachelor's and Master's degrees, with a smaller proportion holding a PhD. This indicates that the sample has a good academic level ranging from moderate to high, which enhances the reliability of the opinions presented and their accuracy in representing the reality of the study.

3.4.2.3 Years of Experience

Table 4: Frequency and Percentage Distribution of the Study Sample by Years of Experience

Years of Experience	Frequency	Percentage (%)
Less than 3 years	9	15%
3 to 5 years	7	11.6%
6 to 10 years	12	21.7%
More than 10 years	32	51.7%
Total	60	100%

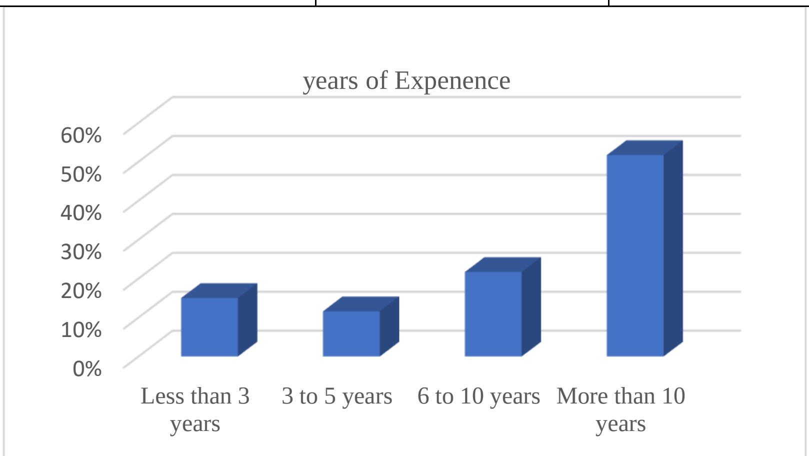

Figure 3: Percentage Distribution of the Study Sample According to Years of Experience.

The data indicate that more than half of the sample have over (10) years of experience, with lower proportions in the other categories. This suggests that the majority of participants possess a high level of professional experience, which gives the results greater strength and depth, and reflects a practical reality based on long experience in the construction field.

Table 5: Frequency and Percentage Distribution of Responses of the Study Sample

Statements							Tot
The importance of using alternative materials improving sustainability	Frequenc	Very important	Importan	Neutr	Not importar	Not importa all	60
		20	11	14	7	8	
	Percentag	33.3%	18.3%	23.3	11.7%	13.3%	100
The extent of your interest in reducing CO_2 emissions	Frequenc	Very important	Importan	Neutr	Not importar	Not importa all	60
		15	4	10	16	15	
	Percentag	25%	6.7%	16.7	26.7%	25%	100
Your level of commitment to implementing sustainability standard	Frequenc	Very high applicatio	High applica	Neutr	Rarely app	Not applied	60
		5	6	17	15	17	
	Percentag	8.3%	10%	28.3	25%	28.3%	100
Evaluation of waste management efficiency	Frequenc	Very poo	Poor	Goo	Very go	Excellen	60
		17	16	15	4	8	
	Percentag	28.3%	26.7%	25%	6.7%	13.3%	100
The extent of improving design efficiency (reducing material usage without affecting safety)	Frequenc	Very poo	Poor	Goo	Very go	Excellen	
		10	7	18	14	11	60
	Percentag	16.7%	11.7%	30%	23.3%	18.3%	100
The extent to which ease of maintenance is considered	Frequenc	Very poo	Poor	Goo	Very go	Excellen	60
		9	5	25	13	8	
	Percentag	15%	8.3%	41.7	21.7%	13.3%	100

The results in Table 5 show a noticeable nice trend near the importance of using alternative products to promote sustainability; However, the expansion of concern in reducing carbon dioxide (CO2) emissions indicates a loss of overall focus on the importance of environmental elements in many, structural designs of respondents .The findings also show that the level of commitment to using sustainable design criteria is very low, with clear deficiencies in waste management and implementation of sustainable practices on construction websites. On the other hand, the responses showed a moderate awareness of the importance of increasing install ability and reducing fabric use without structural protection, followed by appropriate considerations for ease of maintenance. Overall, the results indicate that the adoption of sustainable design remains at a soft level and needs similar support and development.

Table 6: T-Test Results for the Mean Responses of the Study Sample

Statements	Mean	Standard Deviation (SD)	T-test	Level of Agreement
The importance of using alternative materials in improvir sustainability	3.4667	1.40781	19.07412	High
The extent of your interest in reducing CO_2 emissions	2.80	1.527	14.202	Moderate
Your level of commitment to implementing sustainability standard	2.45	1.241	15.293	Low
Evaluation of waste management efficiency	2.50	1.334	14.516	Low

The extent of improving design efficiency (reducing material usage without affecting safety)	3.15	1.325	18.409	Moderate to High
The extent to which ease of maintenance is considered	3.10	1.203	19.959	Moderate to High

The results in Table 6 confirmed a high level of conclusion on the importance of using opportunistic steps to help sustainability, and showed an enormous focus among structural engineers on the importance of sustainable practices in the field of creation. The findings also showed that the level of interests changed mildly with the reduction of carbon dioxide (CO2) emissions, indicating that environmental identity should nevertheless be strengthened and traded off equally as environmental subcultures.

The level of agreement on waste and efficiency on dedication to promoting sustainable design standards has decreased, indicating the life of an opening between the theoretical object and the sustainability practice and rational software .On the opposite side, the results pointed to improving the efficiency of installation and considering easy maintenance, as the settlement levels ranged from soft to high This shows interest in operational elements while maintaining structural safety and improving structural performance.

Table 7: Frequency Distribution of Questions with Binary and Multiple-Choice Options

SN.	Statements						
1-	Nature of Work	Options	Design	Supervision	Execution	Consultancy	Others
		Frequency	23	22	19	26	10
		Percentage	38.3%	36.7%	31.7%	43.3%	16.7%
2-	Type of Projects	Options	Residential	Commercia	Industrial	Infrastructure	Others
		Frequency	47	36	19	18	13
		Percentage	78%	60%	32%	30%	22%
3-	Do you use alternative materials in concrete?	Options	Yes			No	
		Frequency	27			33	
		Percentage	45%			55%	
4-	Percentage of Alternative Material Usage	Options	Less than 10%	10–20%	21–40%	More than 40%	
		Frequency	44	13	2	1	
		Percentage	73.333%	21.667%	3.333%	1.667%	
5-	Type of Materials Used	Options	Fly Ash	Pozzolan	Slag	Recycled Materials	Others
		Frequency	11	7	5	16	38
		Percentage	18.33%	11.67%	8.33%	26.67%	63.33%
6-	Do you take into consideration reducing carbon emissions?	Options	Yes			No	
		Frequency	38			22	
		Percentage	63%			37%	
7-	Do you use methods to reduce emissions?	Options	Yes			No	
		Frequency	27			33	
		Percentage	45%			55%	
8-	Methods Used	Options	Reducing Cement	Alternative Materials	Mix Design Optimization	Precast Concrete	Others

			Conte				
		Frequency	14	14	26	17	16
		Percentage	23.33%	23.33%	43.33%	28.33%	26.67%
9-	Do you apply sustainability standards?	Options	Yes			No	
		Frequency	39			21	
		Percentage	65%			35%	
10-	Systems Used	Options	Green star	BREEAM	LEED	Others	
		Frequency	28	4	11	24	
		Percentage	46.667%	6.667%	18.333%	40%	
11-	Is waste management implemented in projects?	Options	Yes			No	
		Frequency	34			26	
		Percentage	57%			43%	
12-	Recycling Rate	Options	Less than 25%	25–50%	51–70%	More than 70%	
		Frequency	46	14	0	0	
		Percentage	76.67%	23.33%	0.00%	0.00%	
13-	Is service life taken into consideration?	Options	Yes			No	
		Frequency	51			9	
		Percentage	85%			15%	
14-	What are the main obstacles?	Options	Cost	Lack of expertise	Material shortage	Lack of regulations	Time constraints
		Frequency	42	33	18	28	10
		Percentage	70%	55%	30%		

The results presented in Table 7 showed a diversity in the nature of participants' work, with high proportions concentrated in the fields of consultancy, design, and supervision. This enhances the reliability of the opinions provided due to their professional experience. The data also indicated that most of the projects in which the participants are involved fall within residential and commercial buildings, reflecting the broad application of sustainability concepts in the construction sector. Regarding the use of alternative materials in concrete, the results showed that a limited proportion of participants actually rely on them in practice, as usage rates for most of them were less than (10%), indicating that practical application is still at a limited level. The materials used also varied, with recycled materials and other materials being the most common among participants. The results further showed a noticeable interest in reducing carbon emissions, as a good proportion of participants reported taking this aspect into consideration. However, the percentage of those who actually apply practical methods for reducing emissions remained limited, with the most prominent method being concrete mix optimization. On the other hand, the results indicated that the majority of participants apply sustainability standards in their projects, with the Green Star system emerging as the most commonly used system, followed by the LEED system, reflecting the growing interest in environmental assessment systems. The data also indicated an increasing interest in waste management and consideration of project life cycle (service life), which reflects growing awareness of long-term sustainability principles. However, cost emerged as the most significant barrier to the application of sustainability practices, along with lack of expertise and absence of regulatory frameworks, which explains the continued gap between theoretical awareness and practical implementation.

4.Discussion of Results

The findings of take a look at showed that structural engineers have a surprising level of awareness of the importance of using opportunity levels to achieve sustainability but, now this awareness is not fully reflected in actual implementation. This finding is consistent with (Ahmed et al. ,2023[4]), who pointed out that weak policies, limited information on existing technologies, and monetary constraints are among the essential constraints hindering the adoption of sustainability practices. This is also consistent with (Al-Otaibi et al. ,2024[8]), who showed that technical and operational demanding conditions, however, limit the overwhelming use of green concrete.

The results also confirmed that the level of challenge on environmental issues such as reducing carbon emissions moderated, which indicates an insufficient level of environmental awareness This finding (Global Cement and Concrete Association.,(2025[10]) is in roof, with strong legal and institutional support for the implementation of carbon reduction adoption of carbon reduction solutions .Moreover, the study demonstrated a clear weakness in the commitment to applying environmental standards and sustainability principles within the workplace environment. This may be attributed to weak regulatory frameworks and the absence of mandatory sustainability codes, which supports the conclusions of (Neidl.,2022[7]), who highlighted the importance of governmental policies and performance-based standards in promoting the adoption of low-carbon concrete and sustainable construction practices Regarding waste management, the findings revealed significant deficiencies in efficiency and management techniques. This result is consistent with (Habibi et al. ,2024[9]), who stated that existing manufacturing technologies, such as 3D concrete printing, can significantly reduce waste and improve textile performance, yet their software is still limited due to technical and operational challenges. On the alternative side, the results showed a favourable trend toward increasing design efficiency and reducing fabric consumption without compromising structural preservation. This finding is consistent with (Talaat et al. ,2026), who emphasized that early design options do a great job of reducing the embodied carbon footprint and improving structural performance and sustainability. The study also showed that consideration of maintenance aspects was at a moderate level, reflecting an initial awareness of long-term sustainability concepts; however, further development and integration into professional practices are still required. Furthermore, the results showed that the use of concrete alternative products remains compelling for most individuals, with the use rate often below 10% This shows the persistence of technical and regulatory concerns associated with sustainable materials, which is consistent with) Barbhuiya et al., 2025[2]) at molo marketing. availability of. conditions and regulatory restrictions.

Despite these challenges, the findings demonstrated a growing trend toward the adoption of sustainability concepts in engineering and construction projects, along with clear interest in reducing carbon emissions through improved concrete mixtures and the use of alternative materials. The results also showed an increasing application of sustainability rating systems such as LEED and Green Star, reflecting the growing professional awareness of integrating sustainability into design and construction processes.

Overall, the findings suggest that increasing the adoption of sustainable design in high-strength concrete systems requires technology that includes stronger regulations, institutional support, technology development, and expert training to translate theoretical awareness into practical effectiveness in the construction sector.

5. Conclusion and Recommendations

5.1Conclusion

The observation concluded that structural engineers have an awful level of awareness of sustainable design principles in reinforced concrete structures; however, their discretionary utility remains limited due to demanding technical, regulatory, and financial conditions. The findings confirmed some trends in design optimization practices, material discounting techniques, and the use of sustainability rating systems such as LEED and Green Star, although the use of opportunity levels and efficient waste management practices remains limited. Overall, the study emphasizes that effective sustainability requires an inclusive approach of supportive policies, institutional commitment, technology development and expert training if you are to translate focus into powerful practical implementation within the manufacturing sector.

5.2 Recommendations

Based on the findings from the take a look at and the dialogue, which highlighted several challenges and opportunities related to the adoption of sustainable design in reinforced concrete systems, the take a look at recommends the following:

1- To increase the practical implementation of sustainability requirements in creation activities by using to link theoretical knowledge with real operations, thus contributing to the powerful adoption of sustainable building standards.
2- To increase the environmental and professional recognition of engineers and specialists in the construction sector, especially on reducing carbon emissions and their environmental impact, together with the implementation of specialized school package courses to improve the ability of engineers and contractors to use sustainable practices.
3- To develop production, demolition and waste management systems and adopt more green, modern recycling and recycling methods in order to reduce environmental impact and maximize the use of relief measures.
4- Encourage the use of practical options and recycled materials by establishing clean rules and regulations, and in addition to strengthening the institutional review helps to enhance the implementation of low-carbon responses within the creation sector.
5- Focus on enhancing the structural design and adoption of global sustainability assessment systems that will reap improved performance in aid application, beautify the survivability and operational overall performance of the supplier of engineering efforts, and guide long-term sustainable development aspirations.

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