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An Exploratory Quantitative Survey on Practitioner Perceptions of Recycled Construction Debris as Engineered Fill in the Philippines

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ABSTRACT: Increasing construction waste has become a major global environmental and engineering concern. Thereby, this study examines practitioner perceptions on the potential use of recycled concrete debris as an alternative material for engineered fill applications. This study employed a quantitative descriptive survey design, supplemented by one open-ended question, to examine civil engineering practitioner perceptions, involving 41 respondents in the Philippines, which is considered acceptable for perception-based study. With purposive and convenience sampling, the findings are exploratory in nature and are not intended to be generalized to all engineering practitioners in the Philippines. Data were collected through online survey questionnaires, and analyzed using both descriptive (Mean, Percentage) and inferential statistics (ANOVA) to interpret the data. These results indicate that respondents across different professional backgrounds generally share consistent perceptions regarding the structural performance, environmental impact, economic considerations, and implementation feasibility of recycled construction debris. These findings reflect respondent perceptions and not actual engineering performance. Therefore, it is concluded that the respondents generally expressed favorable perceptions toward the possible use of recycled construction materials, regardless of professional classification or level of experience. However, these conclusions are based on perceived knowledge rather than experimental validation, reinforcing the need for further industry-supported implementation frameworks.

KEYWORDS: Construction and Demolition Waste, Recycled Engineered Fill, Concrete Debris, Practitioner Perception, Philippines

1.0 INTRODUCTION

THE PROBLEM AND ITS BACKGROUND

Increasing construction waste has become a major global environmental and engineering concern. According to Roy and Beulah (2024), the construction industry significantly contributes to global waste through material offcuts, packaging, and unused materials. Building activities consume large amounts of natural resources such as sand and gravel while producing substantial waste. In developing countries like the Philippines, the Department of Environment and Natural Resources notes that solid waste remains a major environmental issue due to open dumpsites and poor waste management. Rising landfill costs, limited landfill space, and the depletion of natural aggregates have driven the need to recycle concrete demolition waste, promoting environmentally sustainable practices (Serres et al. 2016).

Construction generates large quantities of on-site waste, making it a key contributor to environmental degradation (Salah et al. 2025). The growing demand for building materials also increases total solid waste output (Gunja, 2022). The Department of Public Works and Highways highlights that infrastructure projects significantly impact the environment, stressing the importance of sustainable construction and proper waste management practices such as reducing, reusing, and recycling.

Despite policies like RA 9003, solid waste management continues to pose challenges in the Philippines. Bueta, Domingo, and Manejar (2024) emphasize the need for alternative approaches to address growing waste generation. Long-term waste accumulation and dumpsite overuse have led to environmental and safety concerns due to limited landfill capacity (Delos Reyes et al., 2011). Recent Philippine studies advocate recycling and resource recovery, particularly the use of construction waste as alternative aggregates. The Philippine Institute for Development Studies supports reusing concrete waste and agricultural by-products to extend material life and reduce dependence on natural resources. This approach prioritizes durability and adaptability, promoting sustainable consumption and waste reduction.

In response to the growing waste problem, this study investigates civil engineers' perceptions of using recycled concrete debris as an alternative material for engineered fill in Nueva Ecija. The research aims to contribute to sustainable waste management practices and support the potential adoption of recycled materials in the construction industry.

2.0 REVIEW OF RELATED LITERATURE

2.1 Overview

The reuse of construction and demolition (C&D) waste as engineered fill offers a sustainable solution to the growing problem of construction waste. C&D waste, composed mainly of concrete, bricks, and other inert materials, arises from construction, renovation, demolition, and natural disasters (Menegaki & Damigos, 2018; Wu et al., 2014). Despite its reuse potential, much of it is still disposed of in landfills, causing environmental and health issues (Menegaki & Damigos, 2018; Mália et al., 2013). Research highlights the recyclability of these materials and the shift toward sustainable waste management (Wu et al., 2014; Mália et al., 2013). Several countries have demonstrated high recycling rates, reinforcing the feasibility of reusing C&D waste in construction (Mália et al., 2013).

2.2 Technical Feasibility of Recycled C&D Waste as Engineered Fill

Studies confirm the technical viability of C&D waste as engineered fill when properly processed and compacted. C&DW from concrete, bricks, mortar, and ceramics retains favorable physical properties, making it suitable for geotechnical use (Yılmaz et al., 2018). Partial soil replacement with C&DW improves maximum dry density, internal friction angle, and shear strength (Prajapati & Rangwala, 2022). Recycled materials show comparable performance to conventional backfill and are suitable for road bases and embankments. Research also supports its use in underground filling applications, where it enhances strength and stability (Yılmaz et al., 2018; Zhang et al., 2020; Santos et al., 2014).

2.3 Environmental Benefits and Durability Behavior

Reusing C&DW reduces landfill load and conserves natural aggregates, aligning with circular economy principles (Yılmaz et al., 2018). Although recycled materials have higher porosity and water absorption, proper processing allows them to meet construction performance standards (Ok et al., 2020). Long-term studies show that durability issues related to moisture and chemical exposure can be mitigated through appropriate engineering practices (Yılmaz et al., 2018). Thus, environmental and durability concerns are manageable rather than prohibitive.

2.4 Economic Considerations

Economically, reuse lowers costs by reducing landfill fees and dependence on virgin aggregates (Yılmaz et al., 2018; Mália et al., 2013). However, expenses for sorting, crushing, and testing can offset these savings. Material variability and strict quality standards may also raise costs. Despite this, increasing landfill scarcity and regulation strengthen the long-term economic viability of recycled fill materials.

2.5 Barriers to Adoption

Adoption is hindered by regulatory gaps, client demand issues, and perception barriers. While practitioners recognize recycling's benefits and show willingness to adopt it (Tam et al., 2018; Jin et al., 2017), implementation remains limited due to weak enforcement and lack of standardized specifications (Park & Tucker, 2016). Material variability reduces trust, but hands-on experience improves perception and acceptance (Jin et al., 2017). Demonstration projects and training programs can help bridge this gap.

2.6 Research Gap: Philippine Context

Most research originates from developed countries, leaving a gap in data on local perceptions in the Philippines. The country's growing construction sector, limited recycling infrastructure, and evolving policies necessitate localized studies (Menegaki & Damigos, 2018; Wu et al., 2014). Understanding Filipino practitioners' views on recycled C&DW is crucial for formulating effective regulations and encouraging sustainable use in local construction practice.

3.0 RESEARCH DESIGN AND METHODOLOGY

This chapter reveals the methods of research to be employed by the researcher in conducting the study which includes the method and technique used, research locale, population and sampling procedures, construction and validation of instruments, data gathering process, and data analysis and technique.

3.1 Research Method and Technique Used

The researcher employed the quantitative descriptive survey design with one open ended question research method as the design to evaluate perceptions regarding the perceived suitability of recycled construction debris as a possible engineered fill material, such as construction debris, as a sustainable alternative to natural aggregates in civil engineering materials in the Philippines. This method will be used to gather data about varying subjects and will conduct a survey questionnaire to gather information that is needed for this study.

3.2 Research Locale

This study is conducted in the Philippines; this place is the most suitable as it covers a wide range of respondents because the respondents must be engineers that have knowledge about construction. This study wants to assess the engineers' perceptions regarding recycled construction waste concrete-based, such as construction debris as a sustainable alternative to natural aggregate in civil engineering. The study will be conducted in many places around the Philippines to gather respondents that are engineers.

3.3 Population and Sampling Procedures

The study focuses on engineer practitioners practicing in the Philippines, as they possess the necessary technical knowledge and experience in construction activities such as material utilization, site development, and construction waste management. These professionals are considered suitable respondents because of their direct involvement in the field and familiarity with construction practices.

To meet the objectives of the study, a non-probability sampling method was utilized, specifically purposive sampling, to select respondents who meet the following criteria: (1) must be a licensed civil engineer or civil engineering practitioner in the Philippines; (2) must have current or previous experience in construction projects; and (3) must have knowledge of construction materials and waste management practices. Convenience sampling was also applied by reaching respondents through professional connections, organizations, companies, and online platforms.

The study gathered a total of **41 respondents**, which is considered acceptable for an exploratory or perception-based study. The sample provides exploratory insights and is not statistically representative of the entire civil engineering population in the Philippines. As supported by Memon et al. (2020), citing Roscoe's (1975) rule of thumb, a sample size ranging from 30 to 500 is generally appropriate for most research. Given the exploratory nature and non-probability sampling, the sample size is sufficient for identifying preliminary patterns but is limited for statistical generalization to provide preliminary insights and identify trends in engineers' perceptions. Also, inferential results are exploratory and not generalizable.

However, since the study employed purposive and convenience sampling, the findings are **exploratory in nature and are not intended to be generalized to all engineering practitioners in the Philippines**. Instead, the results provide an initial understanding of industry perceptions regarding the potential suitability of recycled construction waste as engineered fill material.

Specifically, the respondents were primarily drawn from **Nueva Ecija and Metro Manila**, representing both provincial and urban construction environments. Participation was voluntary, and all respondents were informed about the purpose of the study. Their identities were kept confidential, and all collected data were used strictly for academic purposes.

3.4 Instruments of the Study

This research will be conducted to obtain a deeper understanding about the knowledge/familiarity of professionals from different fields in the industry of constructions and years of experience in handling construction debris in the Philippines. The researchers will use questionnaire-based collection of data through an online platform, Google forms.

Firstly, the researchers analyzed the background of the study to make a fitted set of categories of questions. The survey questionnaire will be based on foreign studies—from Latvian, and Malaysia. Second, the questionnaire for construction companies was developed following a review of prior surveys on related topics carried out in other nations. It was subsequently prepared for Engineering practitioners currently working in the Philippines in the year of 2026. The questionnaire will be based on similar research examining perceptions and the current state of the construction waste industry. In designing this questionnaire to achieve the study's goals, certain interview methods and key areas of focus from those studies were considered. To ensure a reliable data interpretation, the questionnaire featured multiple-choice questions, and responses structured using a 1 to 5 Likert Scale. This scale is often used for surveys assessing the level of agreement or disagreement. Each set of categories aims to answer the following questions:

Knowledge/familiarity of Construction Waste Recycling

1. What is the level of knowledge/familiarity among civil engineers regarding the recycling of construction waste as engineered fill in the Philippines?

Perception on the Use of Recycled Construction Debris as Engineered Fill

2. What is the perception of civil engineers regarding the potential suitability of recycled construction debris as engineered fill in terms of:
   a. Perceived structural reliability;
   b. Perceived environmental implications;
   c. Perceived economic considerations;
   d. Perceived implementation feasibility?
   Perceived Challenges and Barriers
3. What challenges or concerns do civil engineers perceive in the use of recycled construction debris as engineered fill?

3.5 Reliability and validity of research instrument

The research instrument used in this study was a structured survey questionnaire designed to gather data on civil engineers' perceptions of recycling construction debris as engineered fill in the Philippines. The questionnaire consisted mainly of close-ended questions with predetermined responses, Likert-scale items, and one open-ended question to capture additional insights from respondents. Questionnaires are widely used in research because they allow the systematic and standardized collection of quantitative data from respondents in a cost-effective and efficient manner (Taderhoost, 2022). They also provide respondents with sufficient time to think about their answers and ensure confidentiality, which can improve the accuracy and honesty of responses (Lee, 2006).

The use of close-ended questions and Likert-scale items enhanced the reliability of the instrument by ensuring uniformity and comparability of responses across participants. Likert-scale questions are commonly used in measuring attitudes, beliefs, and perceptions because they allow researchers to quantify subjective opinions and analyze them statistically. Meanwhile, the inclusion of one open-ended question provided respondents the opportunity to express additional opinions and insights that may not have been captured in the structured questions, thereby strengthening the validity of the data collected.

To ensure content validity, the questionnaire items were carefully constructed based on the objectives of the study. According to Lee (2006), questionnaire items must meet a high degree of applicability and technical quality to effectively measure respondents' attitudes and perceptions.

The study employed purposive sampling to select respondents who met specific criteria: (1) licensed civil engineers in the Philippines, (2) with current or previous experience in construction projects, and (3) with knowledge of construction materials and waste management practices. Purposive sampling is appropriate when researchers need respondents who can provide relevant and useful information related to the research problem (Campbell et al., 2020). This sampling approach ensured that the participants possessed the necessary professional background and expertise to provide reliable and valid responses regarding the recycling of construction debris as engineered fill. Furthermore, purposive sampling allows researchers to focus on specific groups that hold important and informed views on the research topic, thereby improving the credibility and relevance of the findings (Campbell et al., 2020).

3.5.1 Pilot Testing of the Research Instrument

Prior to the conduct of the actual survey, a preliminary pilot test was carried out to assess the clarity, relevance, and usability of the questionnaire. The instrument was reviewed by two civil engineers and one engineering practitioner with relevant experience in sustainable construction practices. Feedback was used to refine the wording, structure, and technical clarity of the items. The pilot respondents were selected based on their professional experience and relevance to the study topic, ensuring technically informed feedback despite the limited number.

3.5.2. Cronbach's Alpha coefficient

To ensure the internal consistency of the survey questionnaire, Cronbach's Alpha was used. This statistical measure determines how closely related a set of items are as a group and is commonly applied to Likert-scale instruments.

The Cronbach's Alpha coefficient is computed using the formula:

$$\alpha = (k / (k - 1)) * [1 - (\Sigma\sigma_i^2/\sigma_t^2)]$$

Where:

α: Cronbach's alpha

k: Number of items

σ_i^2: The sum of the variances of all individual items.

σ_t^2: The total variance of the observed test scores (the sum of all item scores for each participant).

Interpretation

The reliability of the research instrument was assessed using Cronbach's Alpha to determine the internal consistency of the survey items across all variables. The results show that all constructs obtained Cronbach's Alpha values ranging from 0.811 to 0.862, which are interpreted as good reliability. Specifically, Knowledge/Familiarity (0.837), Structural Reliability (0.860), Environmental Implications (0.862), Economic Considerations (0.844), and Implementation Feasibility (0.811) all indicate strong internal consistency among the items under each variable. Overall, these findings suggest that the questionnaire is a reliable instrument for measuring the perceptions of civil engineers regarding the use of recycled construction debris as engineered fill, and it is suitable for further statistical analysis in the study.

3.6 Data Gathering Procedure

After the research instrument was developed and approved by the research instructor, the researchers proceeded with the data gathering process. The **questionnaires were converted into an online format** using Google Forms to make them more accessible to the target respondents.

The researchers first secured permission by sending formal emails and messages to various construction companies to request approval for conducting the survey among their civil engineers. In addition, the researchers individually contacted potential respondents through email and messaging platforms to invite them to participate in the study. Furthermore, various online platforms were utilized to identify and connect with civil engineers who met the qualifications of the study, instead of directly distributing printed questionnaires.

During the data gathering process, certain limitations were encountered. Since most of the target respondents were located in distant areas, face-to-face distribution of questionnaires was not feasible due to logistical constraints. As a result, Google Forms was used as a more efficient and accessible method of data collection.

After the required number of responses was obtained, the researchers retrieved the data from Google Forms and reviewed the responses to ensure completeness and accuracy. Incomplete or invalid responses were excluded from the final dataset used for analysis.

3.7 Data Analysis and Statistical Treatment of Data

The data gathered from the survey questionnaire will be organized and analyzed using both **descriptive statistics** and **inferential statistics** to interpret the responses of the civil engineers regarding the recycling of construction debris as engineered fill:

3.7.1 Descriptive Statistics

Descriptive statistics will be used to summarize and present the data numerically, providing a clear picture of the:

1. Respondents' profile in terms of:
   a. years of experience;
   b. licensure status;

c. professional role/position?

2. Level of knowledge/familiarity among civil engineers regarding the recycling of construction waste as engineered fill in the Philippines.
3. Perception of civil engineers regarding the potential suitability of recycled construction debris as engineered fill in terms of:

a. Perceived structural reliability;
b. Perceived environmental implications;
c. Perceived economic considerations;
d. Perceived implementation feasibility?

1. Challenges or concerns do civil engineers perceive in the use of recycled construction debris as engineered fill.

Likert Scale

Likert scale is a psychometric scale commonly used in questionnaires, and is the most widely used scale in survey research (Sida, 2018). The responses to the Likert scale items will be assigned numeric values from 1 to 5, with 1 representing the lowest level of agreement or awareness and 5 representing the highest.

Frequency and Percentage

The statistical technique used by the researcher will be the Frequency and Percentage formula, to describe respondents' profile, level of knowledge/familiarity, perceptions, and concerns regarding the use of recycled construction debris as engineered fill.

Weighted Score Mean

This another statistical technique will be used by the researcher to determine the average responses of the different options provided in the parts of the questionnaire used. The method will be used in relation to Likert Scale. The mean and overall mean will be used to describe the validity of the responses.

The mean will be computed using the formula:

$$\bar{x} = \sum(f \times x)/n$$

Where:

$\bar{x}$ = mean

$\sum$ = summation symbol of all values in the dataset

F = frequency

x = numerical rating

n = number of respondents

Meanwhile, the overall mean will be computed using the formula:

$$\bar{X} = \sum(f \times \bar{x})/n$$

Where:

$\bar{X}$ = overall mean

$\sum$ = summation symbol of values in the dataset

F = frequency

$\bar{x}$ = mean for each criterion

n = number of questions in survey

3.7.2 Inferential Statistics (ANOVA)

The data gathered from the survey questionnaire will be organized and analyzed using descriptive statistics (frequency, percentage, and weighted mean) and inferential statistics, specifically Analysis of Variance (ANOVA), to determine whether there are significant differences in the perceptions of civil engineers when grouped according to their professional profile.

Inferential statistics were used for comparison within the sample only and do not imply population-level generalization due to the non-probability sampling approach. However, considering the possibility of small subgroup sample sizes, the results of the inferential analysis will be interpreted with caution. The findings will be limited to the respondents of the study and will not be generalized beyond the sample.

1. Is there a significant difference in perception when respondents are grouped according to:
   a. years of experience;
   b. licensure status;
   c. professional role/position?

The formula for F-statistics will be:

F=Mean Square Between Groups (MSB)/Mean Square Within Groups (MSW)

Where:

F = ANOVA Coefficient

MSB = Mean Square Between Groups

MSW = Mean Square Within Group

Formula for MST:

$$MSB = SSB/k-1$$

$$SSB = \sum n_i(x_i-\bar{x}_{grand})^2$$

Where:

k = Total number of groups

n_i = Total Number of samples in group i

x_i = Mean of group i

SSB = Sum of squares due to treatment

$\bar{x}_{grand}$ = Mean of all data value

Formula for MSW:

$$MSW = SSW/n-k$$

$$SSW = \sum(x-\bar{x}_{group})^2$$

Where:

SSW = sum of squares due to error

$\bar{x}_{group}$ = Mean of all data under group

n = Total number of observations

k = Total number of groups

Formula for t-statistic (Unequal Variance)

$$t = (\bar{x}1-\bar{x}2)/\sqrt{((s1^2/n1)+(s2^2/n2))}$$

Where:

t = t-computed value

$\bar{x}1$ = Mean of the first group

$\bar{x}2$ = Mean of the second group

$s1^2$ = Variance of the first group

$s2^2$ = Variance of the second group

n1 = Number of samples in the first group

n2= Number of samples in the second group

Degrees of Freedom (df) for T-test:

$$df = (s1^2/n1 + s2^2/n2)^2 / (((s1^2/n1)^2/n1-1) + ((s2^2/n2)^2/n2-1))$$

Where:
$s1^2$ = Variance of the first group
$s2^2$ = Variance of the second group
n1 = Number of samples in the first group
n2= Number of samples in the second group
For P-value (F-test)
$p=P(F \geq F_{computed})$
For P-value (T-test)
$p=2 \cdot P(T \geq |t_{computed}|)$

Decision Rule:

Reject Ho if F-value ≥ F-critical; there is significant difference

Failed to reject the Ho if F-value < F-critical; there is no significant difference

Reject Ho if |T-score| > T-table ; there is significant difference

Failed to reject the Ho if |T-score| ≤ T-table; there is no significant difference

Reject H_0 if p-value < 0.05 (level of significance); there is a significant difference.

Fail to reject H_0 if p-value ≥ 0.05; there is no significant difference.

4.0 RESULTS AND DISCUSSION

Introduction

After the data were gathered through the survey questionnaire, the researcher proceeded to the analysis and interpretation of the collected data. The study employed a survey questionnaire design to determine the perception of civil engineers regarding the use of recycled construction debris as engineered fill. With the completion of data collection, the next phase involves the presentation, analysis, and interpretation of the findings based on each research variable.

Result of the study

The researchers administered a set of survey questions to determine the perception of civil engineers regarding the perceived sustainability of recyclable construction debris as engineered fill. The responses were analyzed using descriptive statistics, including frequency, percentage, Weighted Score Mean, and verbal interpretation based on a Likert scale.

4.1 Professional Profile of Respondents

4.1.1 Years of Experience

This section presents the distribution of respondents according to their years of experience in the field of civil engineering.

The distribution of respondents shows that 14.6% have less than 1 year of experience, 24.4% have 1–3 years, 31.71% have 4–7 years, 19.5% have 8–15 years, and 9.8% have more than 15 years of experience.

The results indicate that the majority of respondents belong to the 4–7 years category, followed by 1–3 years, then 8–15 years, less than 1 year, and the smallest group being those with more than 15 years of experience. This implies that the study is mainly represented by mid-career professionals, suggesting that perceptions are shaped by engineers with moderate field exposure rather than beginners or highly senior practitioners.

This distribution is consistent with the findings of Wu et al. (2014), where in construction waste management studies are commonly represented by practitioners actively engaged in field operations, as they are directly involved in material handling and project execution.

4.1.2 Licensure Status

The results show that 70.7% of respondents are licensed civil engineers, while 29.3% are non-licensed engineers.

The respondents perceive that the majority of respondents are formally certified professionals, suggesting that the findings are largely grounded in regulated engineering practice. The dominance of licensed engineers implies stronger exposure to professional standards and construction regulations. This is aligned with the discussion of Tam et al. (2018), which emphasized that licensed professionals generally have greater exposure to formal perceived sustainability practices due to regulatory and professional development requirements.

4.2 Professional Role/Position

The majority of respondents are in **Construction Management** (65.85%), followed by **Structural Engineering** (20.95%), some voted for **Others** (12.2%). This implies that most respondents are directly involved in field operations, reflecting practical experience in construction projects. This may provide them with practical insights into construction waste management and its potential applications.

4.2.1 Types of projects commonly held

The results show that 4.9% are involved in residential projects, 34.1% in commercial projects, 4.9% in industrial projects, 17.1% in infrastructure projects, and 39% in mixed projects.

The respondents perceive that mixed projects obtained the highest representation, followed by commercial and infrastructure projects, while residential and industrial projects recorded the lowest percentages. This suggests that respondents are exposed to diverse construction environments, which may influence their understanding of material usage and waste management practices.

This is in line with the observation of Silva et al. (2019), where exposure to multiple construction project types is associated with broader familiarity in the application of recycled aggregates and sustainable construction materials.

4.2.2 Primary Field of Practice

The results show that 7.3% are entry-level engineers, 29.3% are site engineers, 41.5% are project engineers, 7.3% are consultants/designers, and 14.6% are managers or supervisors.

The respondents perceive that the majority of respondents are project engineers, followed by site engineers, suggesting that most participants are actively involved in construction execution and field-based decision-making processes. This strengthens the reliability of responses related to practical construction applications.

This is consistent with the discussion of Jin et al. (2017), where engineers involved in project execution are more exposed to practical issues related to construction materials and waste recycling implementation.

4.3 Level of Knowledge/familiarity

The following sections presents the level of knowledge and familiarity of civil engineers regarding recycled construction debris as engineered fill.

The level of knowledge and familiarity of civil engineers regarding recycled construction debris shows relatively high results across all indicators. For construction waste recycling practices, the weighted mean is 3.92, indicating relatively high familiarity. This suggests that respondents are generally aware of recycling practices in the construction industry. In relation to the use of recycled construction debris as engineered fill, the weighted mean is 3.75, also interpreted as relatively high familiarity, indicating awareness but with moderate practical exposure.

For knowledge of existing recycling practices in the Philippines, the weighted mean is 3.76, showing similar relatively high familiarity. Environmental impact awareness of construction waste disposal obtained a weighted mean of 3.66, still interpreted as relatively high familiarity, though slightly lower compared to other indicators, suggesting moderate awareness of environmental consequences. Exposure to training or seminars related to construction waste recycling recorded the lowest mean at 3.59, but still within relatively high familiarity, indicating that while respondents are aware of the concept, formal training exposure is comparatively limited.

Overall, the results suggest that civil engineers have a generally consistent level of familiarity with construction waste recycling concepts, though direct training exposure appears to be the least developed area. This aligns with findings from Wu et al. (2014), which noted that awareness of construction waste management practices is often present among practitioners, but structured training and implementation exposure remain limited in developing contexts.

4.4 Perception of Civil Engineers

4.4.1 Structural Reliability

The perception of civil engineers in terms of structural reliability shows generally positive responses across all indicators. For the statement that recycled construction debris can achieve adequate compaction when properly processed, the weighted mean is 4.15, interpreted as Agree. For sufficient load-bearing capacity for fill applications, the weighted mean is 3.92, also Agree. Stability under structural loading conditions obtained a mean of 3.80, while long-term performance recorded 3.90, both interpreted as Agree. The statement that performance depends on proper quality control measures obtained the highest mean of 4.20, also Agree.

Overall, the results indicate that respondents generally accept that recycled construction debris may perform structurally perceived as acceptable functions when properly processed and controlled. This aligns with studies such as Zhou and Chen (2017), which emphasized that recycled aggregates can achieve perceived as acceptable mechanical performance when proper quality control and processing methods are applied.

4.4.2 Environmental Implications

All indicators under environmental implications obtained strong positive evaluations. The reduction of construction waste disposal recorded a weighted mean of 4.49, interpreted as Strongly Agree. Contribution to sustainable material management obtained the highest mean of 4.54, also Strongly Agree. Reduction of environmental degradation recorded 4.44, while reduction of demand for natural aggregates obtained 4.26, and conservation of natural resources recorded 4.44, all interpreted as Strongly Agree. These results show a very strong environmental awareness among respondents regarding recycled construction debris.

In addition, Silva et al. (2019), which highlighted that recycled construction materials significantly contribute to reducing environmental burdens by decreasing reliance on natural aggregates and minimizing construction waste disposal.

4.4.3 Economic Considerations

For economic considerations, recycling construction waste improving resource efficiency obtained a mean of 4.17, interpreted as Agree. Reduction of disposal-related expenses recorded 4.24, while processing and transport costs influencing feasibility also obtained 4.24, both Strongly Agree. Recycled materials as viable alternatives when conventional materials are limited recorded 4.22, also Strongly Agree.

Overall, the results indicate that respondents recognize both cost-saving potential and cost-related constraints in the use of recycled materials. This is aligned with Park and Tucker (2016), which noted that economic feasibility in recycled construction materials is strongly influenced by logistics, processing costs, and project-specific conditions.

4.4.4 Implementation Feasibility

For implementation feasibility, the use of recycled construction debris as feasible in construction projects obtained a mean of 4.10, interpreted as Agree. Availability of recycled materials recorded 4.05, while alignment with existing construction practices obtained 3.98, both Agree. Training and awareness influencing acceptance recorded 4.17, and technical guidelines influencing adoption obtained 4.12, both Agree.

Overall acceptance of recommending recycled construction debris obtained a mean of 4.17, also Agree. The results suggest that respondents are generally open to implementation, but recognize that feasibility depends on availability, training, and regulatory frameworks. This is consistent with Tam et al.,(2018), which emphasized that practitioner acceptance of recycled materials is strongly influenced by institutional support, technical knowledge, and industry exposure.

4.5 Challenges and Concerns

4.5.1 On-Site Challenge

The most frequently identified challenge is difficulty in achieving uniform compaction with 51.2%, followed by material contamination issues at 29.3%, equipment wear due to debris characteristics at 19.5%, and health and safety concerns at 14.6%. These results indicate that the main concern is not conceptual acceptance but actual field performance and handling.

This aligns with Zhang et al. (2020), which emphasized that variability in recycled materials significantly affects compaction behavior and field performance, making on-site control a critical factor in successful implementation.

4.5.2 Barriers to Adoption

The results show that lack of technical standards obtained 82.9%, variability in material quality and safety concerns both obtained 63.4%, lack of awareness obtained 53.7%, government support and testing data obtained 48.8%, processing cost obtained 39%, limited availability obtained 36.6%, and contractor/client resistance ranged from 19.5% to 34.14%. The respondents perceive that technical and institutional barriers are more dominant than social resistance factors.

This is aligned with Park and Tucker (2016) and Tam et al. (2018), where the absence of technical standards and limited awareness are identified as major barriers in the adoption of recycled construction materials.

4.5.3 Conditions for Wider Adoption

The respondents identified several key conditions for the acceptance of recycled construction debris as engineered fill. Out of 41 respondents, the majority is 13 which emphasized testing and technical validation as the primary requirement, highlighting the need for sufficient laboratory results, performance data, and verification of material suitability. This was followed by compliance with standards and government regulations (10 responses), where respondents stressed the importance of adherence to national codes, policies, and environmental laws. Meanwhile, material strength, quality, and performance accounted for 9 responses, indicating concerns on durability, compaction, and load-bearing capacity. Environmental safety and cleanliness were mentioned in 5 responses, particularly the need to ensure that materials are free from contaminants and environmentally safe. Lastly, practical considerations such as cost, availability, and industry adoption were identified in 4 responses as factors influencing implementation. These findings suggest that while engineers recognize the potential of recycled construction debris, its acceptance largely depends on verified technical performance, regulatory support, and assurance of safety and practicality in real-world applications.

4.5.4 Perception of Use

The results show that 51.2% of respondents consider recycled construction debris case-dependent, 31.71% view it as a long-term solution, and 17.1% consider it a temporary alternative. The respondents perceive conditional acceptance, meaning usage depends on project requirements, material quality, and engineering judgment.

This aligns with Silva et al. (2019) stating that recycled materials are often applied selectively based on project conditions and performance requirements.

4.6 Significant difference between the perception of civil engineers

4.6.1 Years of experience

The results show that there is no significant difference in the perception of civil engineers regarding recycled construction debris as engineered fill when grouped according to years of professional experience, as determined by One-Way ANOVA, $F(4,36) = 0.071$, $p = 0.99$, indicating that years of experience does not significantly influence respondents' perception.

In terms of mean values, respondents with less than 1 year of experience obtained a mean perception score of 3.886, those with 1–3 years recorded 4.032, 4–7 years obtained 4.086, 8–15 years recorded the highest mean of 4.25, while those with more than 15 years obtained a mean of 4.09. Although slight variations are observed, all groups fall within a close range, indicating relatively consistent perceptions across experience levels.

This suggests that both early-career and highly experienced engineers share similar evaluations regarding the structural, environmental, economic, and implementation aspects of recycled construction debris. The slight increase among the 8–15 years group may reflect greater exposure to field-based decision-making, but the overall pattern respondents perceive that perception is not strongly dependent on experience length.

This finding aligns with Wu et al. (2014), who emphasized that awareness and perception of construction waste management practices are generally distributed across professional levels rather than being limited to seniority or experience.

4.6.2 Licensure Status

In finding the relationship between the perception of licensed and non-licensed civil engineers, the researcher used an independent sample t-test. The results show that there is no significant difference in the perception of licensed and non-licensed civil engineers regarding recycled construction debris as engineered fill, as indicated by an independent samples t-test, $t = 0.341$, $p = 0.735$, meaning licensure status was not found to significantly influence perception within this sample.

In terms of mean values, licensed civil engineers obtained a mean perception score of 4.124, while non-licensed respondents obtained a mean of 4.033, showing only a minimal difference between the two groups. Both groups fall under a high level of agreement, indicating generally positive perception regardless of professional certification.

This suggests that perception is more influenced by exposure to construction practices and perceived sustainability awareness rather than formal licensure status alone. Both groups indicate similar understanding of the potential structural reliability, environmental benefits, and feasibility of recycled materials.

This is consistent with Tam et al. (2018), who noted that attitudes toward recycling practices in construction are primarily shaped by awareness and exposure rather than professional classification.

4.6.3 Professional Role

The results show that there is no significant difference in the perception of respondents when grouped according to professional role, as determined by One-Way ANOVA, $F(2,38) = 0.266$, $p = 0.767$, indicating that job position does not significantly influence perception.

In terms of mean values, structural engineers obtained a mean perception score of 3.98, construction management professionals recorded the highest mean of 4.21, while respondents classified under others obtained a mean of 3.83. Despite minor variations, all groups still indicate a generally positive perception toward recycled construction debris.

This suggests that regardless of professional specialization, engineers share a relatively unified perspective regarding the feasibility and perceived sustainability of recycled construction materials. The slightly higher mean in construction management may reflect direct involvement in project execution and material handling, but the overall results remain statistically insignificant.

This suggests González et al. (2023), who highlighted that perceived sustainability perception in construction is increasingly becoming multidisciplinary, with minimal difference across professional roles.

4.7 Summary of ANOVA Test

Based on the statistical analysis conducted, the study found that no significant differences exist in the perception of respondents regarding the use of recycled construction debris as engineered fill when grouped according to years of professional experience, licensure status, and professional role or position.

These results indicate that respondents across different professional backgrounds tend to share relatively consistent perceptions regarding the structural performance, environmental impact, economic considerations, and implementation feasibility of recycled construction debris. The findings suggest that the acceptance of recycled construction materials may be broadly recognized across the construction industry, regardless of professional classification or level of experience. These findings are consistent with literature on material performance, although this study does not experimentally validate these properties.

5.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Summary of Findings

The following findings were drawn from the analysis of the data.

The most significant number of respondents have a field experience of 4 to 7 years at 31.71% of the total number of respondents. Those who have an experience of more than 15 years had the least portion of the respondents at 9.8% of the total. Most of the respondents were Licensed Civil Engineers at 73.2% of the group, and the remaining 26.8% were all Non-Licensed Civil Engineers. The data collected and analyzed showed that most of the respondents, 65.9% of the group, had a professional position of construction management. The professional roles with the least respondents to which they fall under are transportation infrastructure and water resources, with only one respondent for each. 41.5% of the respondents are most commonly involved in the project engineering practice. The respondents who practiced site engineering were the second most significant at 29.3% of the total.

Furthermore, the data collected and verbally interpreted also showed that most of the respondents had deep understanding with regards to the practice of recycling construction waste and its impact to the environment. Respondents indicated varied perceptions regarding the potential performance of recycled construction debris, particularly in relation to compaction characteristics, load-bearing capacity, structural stability, service life, and the role of quality control measures in ensuring material reliability. A portion of the respondents acknowledged that the utilization of recycled construction materials may contribute to sustainable materials management and improved solid waste disposal practices. These considerations were associated, in some responses, with potential implications for the conservation of natural resources and the mitigation of environmental impacts arising from construction activities.

From an economic perspective, several respondents indicated that recycling construction waste may improve resource use and could be linked to lower costs for materials, transport, and waste management, depending on how it is implemented. Overall, respondents showed varying levels of consideration toward the possible use of recycled construction materials, with some saying they are open to using or recommending them in future projects if performance is proven and standards are properly followed.

Comprising 51.2% of the respondents identified the difficulty in achieving uniform compaction as one of the most notable on-site challenges. Second is the material contamination issues which is identified by 29.3% of the respondents. The findings reveal that civil engineers perceive several key barriers to the adoption of recycled construction debris, with the lack of technical standards identified as the primary concern by 82.9% of the respondents. Other notable challenges include variability in material quality and safety and performance concerns as second most notable concerns having been perceived by 63.4% of the respondents in both of these categories, and lack of awareness among engineers at 53.7%. Additional issues such as limited government support, insufficient testing data, processing costs, and limited availability were also recognized, while client and contractor resistance were considered less significant.

Further, the findings indicate that the acceptance of recycled construction debris as engineered fill primarily depends on testing and technical validation, emphasizing the need for reliable performance data and verification. This is followed by compliance with standards and government regulations, as well as concerns on material strength, quality, and performance. Environmental safety and cleanliness were also identified as important considerations, while cost, availability, and industry adoption were seen as less influential factors. Most of the respondents perceived the use of recycled construction debris to be case-dependent.

Based on the statistical analysis conducted, the study found that there are no significant differences in the perception of respondents regarding the use of recycled construction debris as engineered fill when grouped according to years of professional experience, licensure status, and professional role or position.

These results indicate that respondents across different professional backgrounds generally share consistent perceptions regarding the structural performance, environmental impact, economic considerations, and implementation feasibility of recycled construction debris. These findings reflect respondent perceptions and not actual engineering performance. The findings suggest that the acceptance of recycled construction materials is broadly recognized within the construction industry, regardless of professional classification or level of experience.

5.2 Conclusions

Based on the findings of the study, the following conclusions are drawn:

1. Most of the respondents are licensed civil engineers with 4 to 7 years of experience, primarily engaged in construction management and project engineering. The respondents perceive that they possess relevant practical experience in construction processes and material handling.
2. The study found that civil engineers respondents report relatively high familiarity regarding construction waste recycling and its potential use as engineered fill. They are also knowledgeable about its environmental implications, suggesting that perceived sustainability concepts are generally recognized within the profession.
3. In terms of perception, respondents generally expressed favorable perceptions toward the possible use of recycled construction debris as engineered fill. Although no actual testing has been conducted to verify its structural performance, they believe it may be perceived as acceptable based on practitioner perception if properly processed and managed. They recognize its potential environmental benefits, such as waste reduction and conservation of natural resources, as well as possible economic advantages like reduced disposal costs and improved material efficiency. However, these perceptions remain conditional, as factors such as processing and transportation costs still need to be considered. Wider adoption depends on technical validation, standards development, quality control, and field performance verification.
4. However, several challenges were identified that may limit its use. These include difficulties in achieving uniform compaction, concerns about material contamination, lack of established technical standards, inconsistent material quality, and issues related to safety and performance. These concerns highlight the need for improved regulations and quality control measures.
5. The study also found no significant difference in perceptions when respondents are grouped according to years of experience, licensure status, or professional role. This suggests that perceptions are generally consistent across different professional backgrounds.
6. Overall, the study reveals a generally favorable perception of recycled construction debris as a potential engineered fill material. However, these conclusions are based on perceived knowledge and professional judgment rather than experimental validation, reinforcing the need for further empirical research and industry-supported implementation frameworks. These findings do not confirm engineering suitability and should not be used as a basis for design decisions without proper laboratory and field validation.

5.3 Recommendations

To Future Researchers. Future studies are encouraged to further investigate the long-term performance of recycled construction debris through additional laboratory and field testing.

To Civil Engineers and Practitioners. Engineers are encouraged to apply proper testing, quality control, and careful evaluation when using recycled construction materials in projects.

To Construction Stakeholders. Contractors and project managers are encouraged to practice proper material handling and segregation to ensure quality and reduce contamination.

To Government Agencies. Government agencies are encouraged to develop guidelines and standards for the safe use of recycled construction debris in construction projects.

To Professional Organizations. Engineering organizations are encouraged to promote awareness and training on sustainable construction materials and practices.

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