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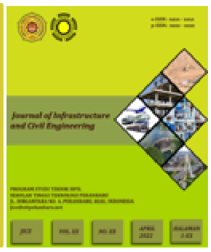

Construction Actors' Perception and Readiness for Environmentally Friendly Soil Improvement in Green Infrastructure Practices

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Abstract

This study aims to assess the perceptions and readiness of construction practitioners regarding the implementation of environmentally friendly soil improvement methods in green infrastructure practices. The study used a descriptive quantitative approach, using a 20-item questionnaire involving 51 respondents active in construction projects. The validity and reliability of the instrument were tested using Pearson correlation and Cronbach's Alpha coefficients, with the majority of items being declared valid (r-value> 0.278) and very high reliability (α = 0.940). The descriptive analysis showed that respondents' understanding of the basic principles of environmentally friendly soil improvement methods was high (mean = 4.08), reflecting a growing awareness of sustainability concepts in geotechnical engineering. However, respondents also identified several implementation barriers, both technical, such as limited equipment and a lack of operational standards, and non-technical, such as budget constraints, resistance to innovation, and minimal local stakeholder participation. Policy support was also deemed insufficiently concrete to encourage the widespread adoption of these methods. The correlation analysis demonstrated a positive relationship between understanding and awareness of implementation challenges. These findings underscore the importance of a collaborative approach and stronger regulatory support to accelerate the adoption of green technologies in the construction sector. The study recommends strengthening technical training, enhancing the capacity of project actors, and developing sustainability-based incentive policies.

Keywords: *soil improvement; green infrastructure; environmentally friendly methods*

1. Introduction

The increasingly apparent global environmental crisis has drawn global attention to the importance of sustainable development[1]. Rising global temperatures, land degradation, the clean water crisis, and declining environmental carrying capacity are urgent issues that cannot be ignored. In the context of physical development, the construction sector is a major contributor to greenhouse gas emissions, energy consumption, raw material exploitation, and environmental pollution. Therefore, transforming the construction sector to become more environmentally friendly is essential to ensure future sustainability. Green infrastructure is emerging as a response to these challenges. This concept emphasizes not only physical development but also environmental conservation, energy efficiency, and ecological balance. Green infrastructure encompasses the application of sustainable principles throughout the

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construction project cycle, from planning and implementation to maintenance. One crucial aspect of green infrastructure is environmentally friendly soil management and improvement. Soil, as the primary medium for foundation structures, plays a vital role in the stability and success of construction. Therefore, soil improvement methods must align with the principles of sustainability and environmental conservation[2].

Environmentally friendly soil improvement methods are civil engineering approaches that seek to reduce negative environmental impacts through the use of sustainable materials and techniques. Examples include the use of natural materials such as lime[3], coconut fiber, or non-toxic industrial waste[4], reinforcement techniques using vegetation or bio-engineering systems; and low-energy geotechnical approaches. These approaches not only reduce long-term costs but also maintain the stability of local ecosystems. However, despite their significant potential, implementation of these methods remains relatively low in many developing countries, including Indonesia. One of the biggest challenges in implementing environmentally friendly soil improvement methods is limited technical understanding among construction workers. Many practitioners in the field are unfamiliar with or lack the adequate skills to adopt these new techniques. Reliance on proven conventional methods, even those not environmentally friendly, is a significant obstacle to transitioning to more sustainable approaches. This can be understood through the social learning theory proposed by Bandura (1986)[5], which states that experience, the environment, and self-efficacy strongly influence individual behavior. Without adequate knowledge and experience, practitioners tend to avoid innovations perceived as complex and risky.

In the Indonesian construction industry, the use of environmentally friendly technologies is generally limited to projects receiving international support or government incentives. Beyond that, the majority of projects are still focused on short-term time and cost efficiency, neglecting long-term environmental aspects. This is exacerbated by the suboptimal regulations and incentive systems that encourage the adoption of environmentally friendly methods. Previous studies have emphasized the importance of integrating policy, technology, and human resource readiness in supporting the transition to sustainable construction [2].

The readiness of construction workers, from cognitive, affective, and technical aspects, is a determining factor in the successful implementation of environmentally friendly soil improvement methods. This readiness includes a conceptual understanding of the methods used, awareness of the importance of environmental aspects in construction work, the required technical skills, and organizational commitment to supporting change. In this regard, education and training play a strategic role. Previous researchers stated suggest that improving the competence of the construction workforce must be part of national policy if Indonesia is to achieve its low-carbon development targets [6].

Furthermore, implementing environmentally friendly soil improvement methods is not only technically relevant but also closely linked to social and cultural values within the community. Green construction requires a shift in mindset and behavior that prioritizes sustainability. Therefore, strengthening positive perceptions of this method's benefits is the first step in opening up wider implementation opportunities. Previous researchers stated note that stakeholder perceptions significantly determine the speed of adoption of new technologies, especially in conservative sectors like construction [7].

Therefore, research into the perceptions and readiness of construction workers towards environmentally friendly soil improvement methods is crucial. This study aims to explore the extent of construction workers' knowledge, understanding, and attitudes towards these methods. By understanding the factors influencing their readiness, it is hoped that appropriate strategies will be found for designing educational interventions, formulating technical policies, and strengthening institutions that support the transformation towards sustainable construction.

Academically, this research makes a significant contribution to enriching the study of sustainable geotechnics and construction organizational behavior. Practically, the results inform decision-making for the government, contractors, consultants, and training institutions in developing capacity-building programs for construction industry players. Ultimately, infrastructure development that is not only robust and efficient but also environmentally conscious will be a key pillar towards a sustainable future.

2. Methodology

The respondents consisted of 51 purposively selected construction workers, specifically those directly involved in construction projects, particularly those related to soil improvement and the implementation of environmentally friendly principles. According to Hair et al. (2014)[8], this number met the minimum requirements for descriptive quantitative research and was sufficient for correlation analysis and instrument validity testing.

Data were analyzed descriptively using means, standard deviations, and trend categories. Additionally, a Pearson correlation analysis was conducted to examine the relationship between construction workers' perceptions and readiness. This study adhered to ethical principles of social research, ensuring confidentiality and voluntary consent from all respondents. This methodology aims to produce a factual and comprehensive understanding of the construction sector's readiness to adopt environmentally friendly soil improvement technologies sustainably.

3. Results and Discussion

Before analyzing the research variables, a respondent characteristics analysis was conducted to obtain a picture of the participants' backgrounds. Demographic information included gender, age, education, position, and length of work experience, which were obtained from the questionnaire identity sheet and presented in frequency and percentage tabulations. This analysis aimed to understand the context of respondents' experiences in assessing the implementation of environmentally friendly soil improvement methods in green infrastructure projects and to serve as a basis for interpreting the research results.

3.1. Analysis of Respondent Data Description

Analysis of respondent characteristics shows that the majority of participants in this study were male, at 98.04%, while females accounted for only 1.96%. This reflects the male dominance in the construction sector, particularly in the context of projects related to land improvement and green infrastructure. In terms of age, the majority of respondents were in the 35–44 years age range (41.18%), followed by the 25–34 years age group (35.29%). This proportion indicates that most respondents are of productive age with the potential for experience and active involvement in construction practices. In terms of educational level, the majority of respondents had a bachelor's degree (S1) at 39.22%, followed by a diploma (D1/D2/D3) at 23.53% and a master's degree (S2) at 18.63%. This proportion indicates that respondents possess sufficient academic capacity to understand technical and environmental issues in construction projects. Based on job title, the majority of respondents worked as implementing/functional staff (33.33%) and operators/field workers (31.37%), reflecting that perceptions and readiness for environmentally friendly soil improvement primarily come from technical personnel in the field.

Meanwhile, based on work experience, those with 6–10 years of experience dominated at 35.29%, followed by those with more than 15 years of experience at 26.47%. These results indicate that most respondents have substantial experience in the construction industry. Therefore, their perceptions and readiness for environmentally friendly soil improvement methods are assumed to be shaped by direct involvement in various projects. Overall, the demographic characteristics of respondents provide a strong contextual basis for assessing the perceptions and readiness of construction personnel to support sustainable infrastructure practices.

3.2. Descriptive Analysis of Respondent Response Data

The variables analyzed cover four main aspects, namely: technical understanding of environmentally friendly methods, technical obstacles that occur in the field, non-technical obstacles such as economic and social aspects, and perceptions of regulatory and policy support. The variables for each aspect are presented in the form of statements used in the questionnaire given to respondents (table 1).

Table 1. Questionnaire Questions

No	Questionnaire Questions	
1	Understanding of Environmentally Friendly Soil Improvement Methods	1. I understand the basic principles of environmentally friendly soil improvement methods.
		2. I am familiar with various types of soil improvement technologies that minimize environmental impacts.
		3. I have participated in training or outreach related to sustainable soil improvement techniques.
		4. I can differentiate between conventional and environmentally friendly soil improvement methods.
		5. The use of natural materials in soil improvement is common practice in the projects I manage
2	Perceptions of Effectiveness and Efficiency	6. Environmentally friendly soil improvement methods are considered adequate in increasing soil-bearing capacity
		7. The cost of implementing environmentally friendly methods is still acceptable compared to conventional methods.
		8. The implementation time for this method is not significantly different from conventional methods.
		9. The effectiveness of environmentally friendly soil improvement methods has been proven through previous projects.
		10. This method strengthens the project's reputation as an environmentally friendly project.
3	Field Implementation Challenges	11. The Lack of experts is a significant obstacle to implementing this method.
		12. The availability of local, environmentally friendly materials is still limited.
		13. Government regulations or policies do not fully support this method.
		14. Coordination between parties (consultants, contractors, government) remains an obstacle to implementation.
		15. Lack of understanding from management results in this method being rarely used.

No	Questionnaire Questions	
4	Institutional and Policy Support	16. The agency where I work is committed to green infrastructure development.
		17. Project policies explicitly encourage the use of environmentally friendly soil improvement methods.
		18. Incentives or awards are available for projects that implement this technique.
		19. The government has provided technical guidance on sustainable soil improvement methods.
		20. National policies on sustainable development encourage the use of this method.

Based on the questions in the instrument, a validity test was conducted to measure the level of validity of each item. Referring to Sugiyono's r-value table as the basis for decision-making, the validity criteria were determined as follows:

1. If the calculated r-value ≥ r-table, the item is declared valid at the 5% significance level.
2. If the calculated r-value < r-table, the item is declared invalid at the 5% significance level.

The r-table is a numerical reference used to determine whether an instrument item is suitable for use based on a correlation test. The r-table value was determined based on the number of respondents studied, which was 51. With degrees of freedom (df) = n – 2 = 49 and a significance level of 5%, the r-table value was 0.278. Based on this value, the results of the instrument validity test, as shown in Table 2, can be summarized as follows:

Table 2. Validity Test Results on Variables

variable	r-value	r-table 5%	description
X1	0,69	0,278	Valid
X2	0,872	0,278	Valid
X3	0,824	0,278	Valid
X4	0,83	0,278	Valid
X5	0,768	0,278	Valid
X6	0,666	0,278	Valid
X7	0,7	0,278	Valid
X8	0,713	0,278	Valid
X9	0,748	0,278	Valid
X10	0,769	0,278	Valid
X11	0,469	0,278	Valid
X12	0,555	0,278	Valid
X13	0,279	0,278	Valid
X14	0,385	0,278	Valid
X15	0,284	0,278	Valid
X16	0,437	0,278	Valid
X17	0,484	0,278	Valid
X18	0,508	0,278	Valid
X19	0,447	0,278	Valid
X20	0,558	0,278	Valid

In detail, of the 20 items tested, 20 were declared valid because they had a significant correlation value with their respective total scores. Items such as X2 (r = 0.872), X4 (r = 0.830), and X10 (r = 0.769) showed very high correlation values, indicating that these items were very representative of the construct being measured. These results indicate that the research instrument generally met the validity requirements.

Reliability testing aims to determine the extent to which an instrument produces consistent and stable data when used in repeated measurements. In this study, reliability testing was conducted using Cronbach's Alpha coefficient, one of the most common methods for measuring internal consistency between items within a construct.

An instrument is considered reliable if the Cronbach's Alpha value is greater than 0.6, indicating that the questionnaire items have an adequate level of interrelationship. Conversely, if the Cronbach's Alpha value is less than 0.6, the instrument is considered unreliable because it indicates low consistency between items. This 0.6 threshold refers to the criteria proposed by Nunnally (1978) and has been widely used in social and behavior research.

Table 3. Reliability Test Results

Reliability Statistics	
Cronbach's Alpha	N of Items
0,940	20

Based on the reliability test results, a Cronbach's Alpha value of 0.940 was obtained for the 20 questions in the research instrument. This value indicates that the instrument has a very high level of internal consistency. Referring to the criteria proposed by Nunnally (1978), a Cronbach's Alpha value above 0.90 is categorized as highly reliable. This means that the questions in the questionnaire show a close relationship with each other in measuring the same construct. Thus, this instrument can be declared highly reliable and suitable for use in collecting data in this study because it is able to produce stable and consistent measurements. These results also strengthen the validity of the data that will be analyzed further in assessing the perceptions and readiness of construction actors towards environmentally friendly land improvement in green infrastructure practices.

3.3. Results of Descriptive Analysis based on Likert scale

The results of the descriptive analysis of each main parameter formed from items X1 to X20 show a relatively high average (mean) value, as shown in the following table:

Table 5.9 Summary of Descriptive Analysis Results of Test Variables

<table>
<tr><th>No</th><th colspan="2">Questionnaire Questions</th><th>Mean</th><th>Std</th></tr>
<tr><td rowspan="2">1</td><td rowspan="2">Understanding of Environmentally Friendly Soil Improvement Methods</td><td>1. I understand the basic principles of environmentally friendly soil improvement methods.</td><td>3,92</td><td>0,935</td></tr>
<tr><td>2. I am familiar with various types of soil improvement technologies that minimize environmental impacts.</td><td>3,86</td><td>0,8</td></tr>
</table>

No	Questionnaire Questions		Mean	Std
		3. I have participated in training or outreach related to sustainable soil improvement techniques.	3,57	1,005
		4. I can differentiate between conventional and environmentally friendly soil improvement methods.	3,73	0,961
		5. The use of natural materials in soil improvement is common practice in the projects I manage	3,88	1,013
2	Perceptions of Effectiveness and Efficiency	6. Environmentally friendly soil improvement methods are considered adequate in increasing soil-bearing capacity	4,06	0,858
		7. The cost of implementing environmentally friendly methods is still acceptable compared to conventional methods.	3,88	0,71
		8. The implementation time for this method is not significantly different from conventional methods.	3,76	0,737
		9. The effectiveness of environmentally friendly soil improvement methods has been proven through previous projects.	3,76	0,839
		10. This method strengthens the project's reputation as an environmentally friendly project.	3,90	0,755
3	Field Implementation Challenges	11. The Lack of experts is a significant obstacle to implementing this method.	4,12	0,765
		12. The availability of local, environmentally friendly materials is still limited.	3,96	0,692
		13. Government regulations or policies do not fully support this method.	3,76	0,839
		14. Coordination between parties (consultants, contractors, government) remains an obstacle to implementation.	3,78	0,640
		15. Lack of understanding from management results in this method being rarely used.	3,80	0,96

No	Questionnaire Questions		Mean	Std
4	Institutional and Policy Support	16. The agency where I work is committed to green infrastructure development.	3,94	0,858
		17. Project policies explicitly encourage the use of environmentally friendly soil improvement methods.	3,76	0,815
		18. Incentives or awards are available for projects that implement this technique.	3,75	0,913
		19. The government has provided technical guidance on sustainable soil improvement methods.	3,69	0,905
		20. National policies on sustainable development encourage the use of this method.	3,88	0,909

a. Understanding of Environmentally Friendly Soil Improvement Methods

Respondents demonstrated a good basic understanding of the principles of environmentally friendly soil improvement (Mean = 3.92), in line with Kibert's (2016)[9] view that environmental literacy reflects readiness to adopt green technology. However, participation in training remained low (Mean = 3.57), indicating the need for enhanced socialization to enable the practical application of this understanding [10].

b. Perceptions of Effectiveness and Efficiency

Respondents considered this method effective in increasing soil bearing capacity (Mean = 3.88), although they remained skeptical about the implementation's time efficiency (Mean = 3.76). This finding supports Zhang et al.'s (2019)[7] argument that perceptions of technical and time-cost efficiency significantly influence the adoption of environmentally friendly technologies.

c. Challenges to Field Implementation

The main obstacles identified were a shortage of experts (Mean = 4.12), followed by limited local materials (Mean = 3.96), and weak regulations (Mean = 3.90). These results indicate that limited technical and structural resources remain significant barriers [6], including suboptimal cross-sectoral coordination (Mean = 3.76).

d. Institutional and Policy Support

Despite organizational commitment to green infrastructure (Mean = 3.94), the availability of incentives (Mean = 3.75) and technical guidance (Mean = 3.69) remains limited. This indicates the need for more concrete and operational policies to ensure the sustainable adoption of environmentally friendly technologies [2]

3.4. Discussion

The descriptive analysis results indicate that respondents generally have a high level of understanding of environmentally friendly soil improvement methods, with an average score of 4.08. According to the five-point Likert scale, this score falls into the "agree" category. This finding indicates that knowledge and awareness of sustainability principles in geotechnical engineering have grown, particularly among professionals and green infrastructure project implementers. This understanding can be attributed to increased environmental campaigns and the integration of green engineering concepts into higher education curricula and technical [9].

However, respondents also identified several significant barriers to implementing these methods. Technical barriers received an average score of 4.05, indicating that limited equipment, the lack of standardized technical standards, and complex local soil characteristics remain significant challenges in the field. This finding aligns with research by[11], which emphasized the importance of adapting technology to local geotechnical conditions and the need to improve technical capacity at the implementation level.

Furthermore, non-technical barriers also emerged, with an average score of 3.86, indicating the influence of social, economic, and institutional factors on successful implementation. Budget constraints, resistance to innovation, and minimal participation by local stakeholders are all factors that hinder the adoption of environmentally friendly technologies. In this context, a collaborative approach between government, academics, contractors, and local communities is essential. This aligns with [6] perspective, which emphasizes that the success of environmentally-based projects is primarily determined by active community involvement and supportive social responses.

Regulatory and policy support was also a concern, with an average score of 3.99. Despite initiatives to develop green regulations, respondents assessed that existing policies were not yet concrete enough to encourage widespread adoption of environmentally friendly methods. This finding corroborates the assertion of Zhang et al. (2019)[7], who stated that without strong policy support and adequate incentives, the adoption of innovation in sustainable construction tends to stagnate.

Furthermore, correlation analysis results indicate a strong and significant relationship between the level of understanding and both technical and non-technical barriers. This positive correlation indicates that the greater the respondents' understanding of environmentally friendly soil improvement methods, the greater their awareness of the challenges faced, both in terms of technical implementation and policy aspects. This finding supports Bandura and Health's (1986)[5] argument that adequate conceptual understanding enables individuals to identify actual obstacles in the implementation process critically.

The reliability test results, with a Cronbach's Alpha value of 0.940, indicate that the research instrument has a very high level of internal consistency. All items in the instrument work harmoniously to represent the constructs studied, allowing the interpretation of the resulting data to serve as a strong foundation for developing policy strategies and implementation recommendations. Overall, the results of this study confirm that although the understanding of environmentally friendly soil improvement methods is at a reasonable level, implementation challenges from both technical and structural perspectives still require serious attention. Therefore, strengthening technical capacity, increasing the involvement of local actors, and developing incentive-based policies are necessary as strategic steps to promote the success of sustainable green infrastructure projects in the future.

4. Conclusion

This study shows that construction practitioners have a relatively high level of understanding of environmentally friendly soil improvement methods, as indicated by an average score in the "agree" category. This reflects an increasing awareness of sustainability principles in geotechnical engineering practices. However, the implementation of these methods still faces several obstacles, both technically, such as limited equipment and the lack of standard operating procedures, and non-technically, including budget constraints, low local stakeholder participation, and suboptimal regulatory support. The findings also indicate that a high level of understanding is positively correlated with awareness of implementation challenges, indicating that sound knowledge enables project practitioners to identify obstacles more critically. Furthermore, the high reliability of the instruments supports the validity of the data obtained, allowing the research results to serve as a basis for formulating policies and capacity-building strategies. Therefore, to encourage the successful implementation of environmentally friendly soil improvement methods in green infrastructure projects, integrated efforts are needed to strengthen technical capacity, increase training and outreach, and provide more concrete, incentive-based policy support. A collaborative, cross-sectoral approach is also key to accelerating the adoption of sustainability-oriented technologies.

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