FACTORS INFLUENCING THE USE OF NON-FIRED BUILDING MATERIALS IN NON-MANDATORY CONSTRUCTION PROJECTS IN BINH DUONG

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Abstract - Binh Duong province is experiencing rapid urbanization, creating a great demand for building materials to support the government's policy of promoting the use of non-fired building materials. This policy aims to gradually reduce and eventually eliminate reliance on fired clay bricks. However, under current regulations, the choice of non-fired materials in construction projects largely depends on the views of investors, planners and possibly contractors. For example, only 20-30% of civil buildings with less than nine floors that are not subject to mandatory legal requirements are built with non-fired materials. Therefore, the increased use of non-fired building materials in Binh Duong is an important issue. This study identifies the factors influencing the selection of non-fired materials and proposes specific solutions to promote their use in non-mandatory construction project in the province.

Key words - Sustainable development; non-fired building materials; Civil construction; construction influencing factors; solutions

1. Introduction

Construction is an industry that makes extensive use of natural resources [1], including non-renewable resources such as soil, minerals, sand, stone and gravel, as well as renewable resources like vegetation (wood from forests) and water. Additionally, it consumes a considerable amount of electricity. In many regions, around 50% of all non-renewable resources consumed by humans are used in the construction sector, making it one of the largest and least sustainable consumers. Land, groundwater and biodiversity can be altered or destroyed by unsustainable construction activities and infrastructure development [2]. Therefore, many countries around the world consider sustainable construction to be a key factor in minimizing negative environmental impacts [3].

In recent years, the building materials industry has undergone a fundamental change from outdated technologies to more modern approaches [4]. New investment projects in building materials production are geared towards the application of advanced technologies, with a focus on conserving natural resources and energy. As a result, numerous environmentally friendly building materials have been developed, leading to a growing proportion of green buildings using these materials in many countries. Therefore, the building materials production sector in Vietnam cannot escape this development trend, in which non-fired building materials play an important role.

Despite national and local policies promoting NFBMs, existing studies indicate that the adoption of these materials remains limited in non-mandatory construction projects. Key challenges include limited awareness among private investors and contractors, misconceptions about the cost and performance of NFBMs, insufficient market availability, and weak enforcement mechanisms [5]. These constraints hinder the widespread adoption of sustainable alternatives in projects not subject to mandatory policy requirements, thereby undermining broader environmental goals.

Binh Duong is among the most rapidly urbanizing provinces in southern Vietnam, with a high concentration of industrial zones and continuous infrastructure expansion. This rapid development exerts substantial pressure on natural resources and the environment. In response, the provincial government has introduced policies consistent with national regulations [6], [7] to promote the use of non-fired building materials (NFBMs), mandating their application in state-funded projects, developments involving over 30% state ownership, and all high-rise buildings (nine stories or more), irrespective of funding source.

However, the use of NFBMs in privately funded low-rise buildings (under nine stories) remains non-mandatory. As a result, adoption rates in this segment are low, with only 20%–30% of projects incorporating NFBMs [8]. This highlights a significant implementation gap in construction activities outside the scope of existing regulatory frameworks [6].

Given these conditions, Binh Duong represents a relevant and insightful case for examining the determinants of NFBM adoption in non-mandatory construction contexts. This study, titled "Factors influencing the use of non-fired building materials in non-mandatory construction projects in Binh Duong" aims to identify the key factors shaping adoption decisions and to provide evidence-based recommendations to enhance the use of NFBMs in privately funded low-rise developments.

2. Research methodology

The study was conducted using a comprehensive approach that included a review of existing literature, consultations with experts in the relevant fields to define the survey points and data collection through surveys of key stakeholders.

2.1. Research diagram

The overall research process of the study is illustrated in the Figure 1 below.

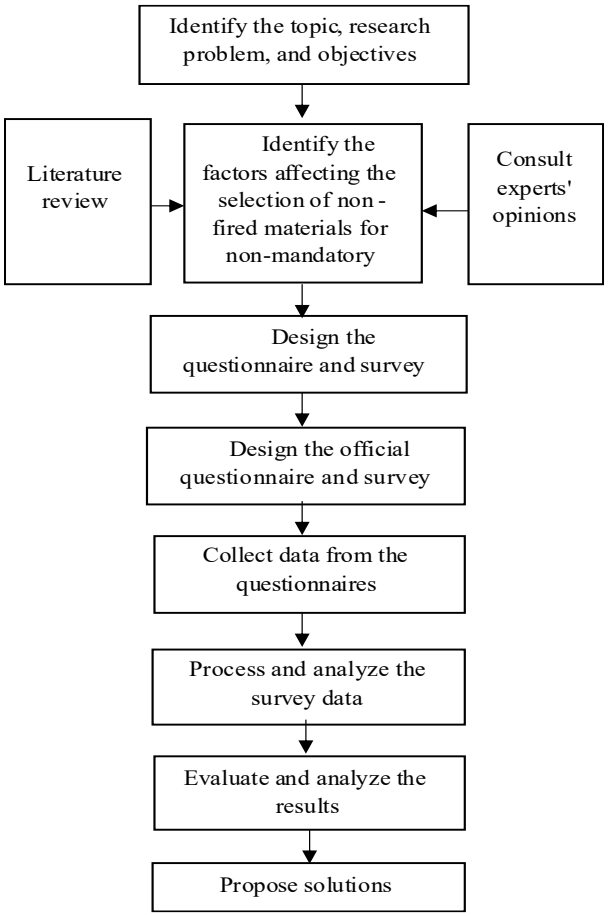

Figure 1. *Research diagram*

2.2. Survey design

The questionnaire was developed to assess the factors influencing the selection of non-fired building materials in Binh Duong province. It includes 20 factors, such as legal regulations, stakeholder perceptions, design/technical requirements and cost considerations, which were grouped into four categories to improve respondents' understanding and facilitate data collection and analysis, as shown in Table 1. The development of the questionnaire was primarily based on expert opinions to ensure its relevance and comprehensiveness. A 5-point Likert scale was used for the responses, with 1 being "strongly disagree", 2 being "disagree", 3 being "neutral", 4 being "agree" and 5 being "strongly agree".

Table 1. *Factors affecting the selection of non-fired building materials in Binh Duong province*

No.	Factors affecting the selection of non-fired building materials in Binh Duong province	Encoding
I. Group of factors related to perception		**NT**
1	Reduction of CO_2 emission	NT1
2	Recyclability and renewability of materials after the building' s lifecycle	NT 2
3	Environmental friendliness of non-fired building materials	NT 3
4	Potential to reduce resource depletion	NT 4
5	Compliance with environmental sanitation regulations and waste management in construction activities using non-fired materials	NT 5
6	Minimization of energy consumption (energy-efficient buildings)	NT 6
7	Contribution to sustainable construction practices	NT 7
II. Group of factors related to design/technical requirements		**TKKT**
1	Compliance with aesthetic design requirements	TKKT1
2	Fulfillment of technical durability requirements	TKKT2
3	Fulfillment of technical requirements for properties such as sound insulation, thermal insulation, moisture resistance, fire resistance, etc.	TKKT3
4	Familiarity of construction workers with using non-fired building materials	TKKT4
5	Understanding of non-fired building materials by the investor, project manager, design unit, and construction contractor	TKKT5
III. Group of factors related to cost		**CP**
1	Cost comparison of non-fired building materials to conventional materials (such as clay bricks), focusing on material cost alone.	CP1
2	Testing costs associated with using non-fired building materials	CP2
3	Construction costs for buildings using non-fired materials once in operation	CP3
4	Construction cost estimation (Using non-fired materials → Reduced building load → Reduced load on the foundation, focusing on the weight of non-fired materials)	CP4
IV. Group of factors related to other elements		**NTK**
1	Construction schedule	NTK1
2	Market availability and penetration of environmentally friendly, non-fired building material	NTK2
3	Compatibility of non-fired building materials with the climate conditions in Binh Duong	NTK3
4	Disadvantages of using non-fired building material	NTK4

2.3. Data processing and analysis methods

Scale reliability testing using Cronbach's alpha: To assess the reliability and internal consistency of the measurement scales, Cronbach's alpha coefficients are calculated using SPSS software. This method can be used to determine the extent to which the items within each scale consistently measure the same underlying construct.

Exploratory factor analysis (EFA): Exploratory factor analysis (EFA) is used to reduce the number of observed variables and identify the underlying factors. This technique helps to simplify the data structure by grouping correlated variables into factors, which helps to understand the underlying dimensions of the data.

Official sample size

For Exploratory Factor Analysis (EFA), the recommended sample size is typically at least five times the number of observed variables, which is considered sufficient for conducting factor analysis [9-10].

Formula: n = 5 * m (where *m* is the number of survey questions).

With 5 independent variables and 20 survey questions, the minimum sample size required is 100.

Sampling technique

The study uses a stratified random sampling sample, with strata based on criteria such as job position and professional qualification.

Data collection method

Quantitative data was collected by distributing structured questionnaires. A total of 150 questionnaires was distributed at construction sites and consulting companies in Binh Duong province.

3. Results and discussion

3.1. Characteristics of the survey population

To comprehensively assess the barriers to the use of non-fired building materials in Binh Duong province, the study conducted a survey of people involved in construction projects in the region. A total of 150 questionnaires were distributed, of which 138 were answered. However, 9 responses were excluded as the participants stated that they had never used non-fired materials in their projects. The general information provided by the survey participants is shown in Figure 2, Figure 3 and Figure 4 as follows.

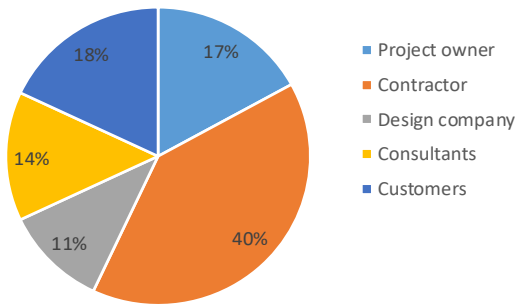

Figure 2. *Educational background of survey respondents*

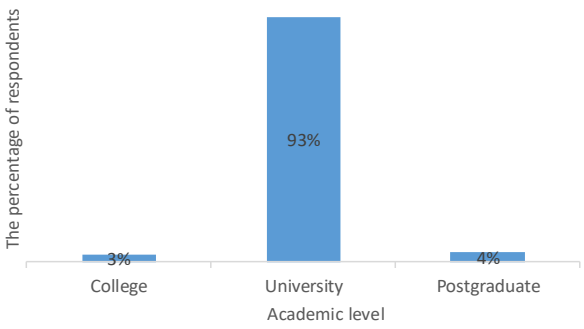

Figure 3. *Demographic composition of survey respondents*

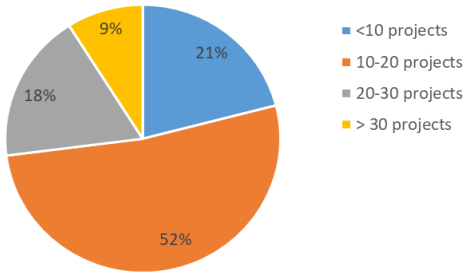

Figure 4. *Survey participants' experience in projects using non-fired construction materials*

The survey results show that all respondents work in the construction industry, with the vast majority of organizations and individuals having a bachelor's degree or higher (97%). In terms of experience, 79% of respondents have been involved in at least 10 projects, and 52% have been involved in 10–20 projects. This indicates that the individuals surveyed have sufficient professional qualifications, a solid understanding of technical details, and a basic understanding of relevant laws and government policies. Based on these survey percentages, the knowledge of the participants can be considered adequate and highly reliable.

3.2. Cronbach's alpha test results

The results of the reliability tests in Table 2 show that the overall coefficients of Cronbach's alpha are greater than 0.6 for all variables. The constructed measurement system - consisting of five scales -thus ensures good quality with 19 characteristic variables. Table 2 presents the final reliability results after excluding NTK3, which was removed due to its total correlation below 0.3.

Table 2. *Reliability test results of the measurement scale*

Criteria	Corrected item-total correlation	Cronbach's alpha if item deleted	Cronbach's alpha
NT1	0.641	0.755	
NT 2	0.346	0.806	
NT 3	0.483	0.784	
NT 4	0.663	0.749	0.801
NT 5	0.465	0.787	
NT 6	0.514	0.779	
NT 7	0.614	0.759	
TKKT1	0.594	0.753	
TKKT 2	0.520	0.777	
TKKT 3	0.458	0.794	0.797
TKKT 4	0.643	0.737	
TKKT 5	0.687	0.725	
CP 1	0.603	0.641	
CP 2	0.535	0.676	0.738
CP 3	0.464	0.716	
CP 4	0.527	0.680	
NTK 1	0.631	0.625	
NTK 2	0.634	0.617	0.757
NTK 4	0.500	0.769	

3.3. Exploratory factor analysis (EFA)

The exploratory factor analysis results for 19 variables are presented in Table 3.

Table 3: Final exploratory factor analysis results

Observed variable	Rotated component matrix			
	F1	F2	F3	F4
NT 1	.793			
NT 4	.768			
NT 7	.710			
NT 6	.649			
NT 5	.589			
NT 3	.586			
NT 2	.528			
TKKT 5		.818		
TKKT 4		.774		
TKKT 1		.738		
TKKT 2		.678		
TKKT 3		.662		
CP 1			.780	
CP 2			.733	
CP 4			.728	
CP 3			.698	
NTK 2				.851
NTK 1				.789
NTK 4				.757
Eigenvalues	4.273	2.606	1.949	1.727
% of Variance	22.487	13.716	10.258	9.091
Cumulative %	22.487	36.204	46.462	55.553

3.3.1. Suitability test for exploratory factor analysis

The results in Table 4 show that the KMO coefficient is 0.772 (> 0.5) and the Bartlett's test for sphericity (test of whether the correlations between the observed variables in the population are zero) gives Sig. = 0.000 (≤ 0.05), indicating that the research data are suitable for factor analysis.

3.3.2. Correlation testing of observed variables in the representative scale

In Table 4, the result of the Bartlett's test is 807.004 with a significance level of Sig. < 0.05. This shows that the data used for the analysis is completely appropriate. Thus, the observed variables show a linear correlation with the representative factors.

Table 4. *KMO and Bartlett's test results*

Kaiser-Meyer-Olkin measure of sampling adequacy		0.772
Bartlett's Test of Sphericity	Approx. Chi-Square	807.004
	df	190
	Sig.	0.000

3.3.3. Testing the explanatory power of observed variables for the factors

The data in Table 3 also show that the eigenvalues representing the proportion of variance explained by each factor group are all greater than 1 and the value of variance extracted is 55.553% (> 50%). This means that the four factor groups explain 55.553% of the variance in the observed variables

3.4. Results of the model after EFA analysis

Through scale testing using Cronbach's alpha and Exploratory factor analysis (EFA), the model was identified with 4 factors and 19 characteristic variables, as described in Table 5.

Table 5. *Adjusted model based on Cronbach's alpha testing and EFA*

STT	Factor	Observed variable	Scale explanation
1	NT	NT1, NT2, NT3, NT4, NT5, NT6, NT7	Perception
2	TKKT	TKKT1, TKKT2, TKKT3, TKKT4, TKKT5	Design & engineering
3	CP	CP1, CP2, CP3, CP4	Cost
4	NTK	NTK1, NTK2, NTK4	Other factors

3.5. Descriptive statistical analysis of the criteria influencing the decision to use non-fired material in Binh Duong province

To facilitate the evaluation and provide recommendations, the study used the mean value to rank the criteria according to their importance in the decision to use non-fired materials in Binh Duong province. The results are shown in Table 6 as follows.

Table 6. *Summary of criteria by level of importance*

STT	Criterion	Importance	Mean	Standard Deviation
1	**NT 3**	**1**	**4.11**	**0.763**
2	**TKKT 4**	**2**	**4.1**	**0.769**
3	**TKKT 5**	**3**	**4.03**	**0.847**
4	**CP 3**	**4**	**4.01**	**0.755**
5	NT 6	5	3.98	0.81
6	NT 4	6	3.95	0.865
7	NT 1	7	3.94	0.798
8	NTK 4	8	3.92	0.863
9	NTK 1	9	3.91	0.833
10	NTK 2	9	3.91	0.897
11	TKKT 3	10	3.89	0.868
12	NT 2	11	3.87	0.896
13	TKKT 2	12	3.84	0.931
14	NT 7	13	3.83	0.858
15	CP 1	14	3.76	0.982
16	TKKT 1	15	3.74	0.931
17	NT 5	16	3.71	0.896
18	CP 4	17	3.67	1.001
19	CP 2	18	3.65	0.997

The ranking based on mean values is only relatively meaningful, as it does not take into account the variance of the distribution and no T-test was carried out to check the statistical significance of the rankings. Nevertheless, the ranking based on mean values gives managers a relative impression of the importance of the factors. The mean

values of the evaluated criteria range between 3.65 and 4.11, and the dispersion of the data, as indicated by the standard deviation, is not large (the highest value is 1.001). This indicates that the survey participants tend to agree with the proposed criteria overall.

The study will focus on analyzing the four criteria from the table above that have a mean score above 4 - which corresponds to the "Agree" level on the survey scale - in order to gain deeper insights into these aspects.

Criterion 1 (NT3) *"Environmental friendliness of non-fired building materials (protection and reduction of harmful environmental impacts, etc.)"*: It is obvious that environmental awareness influences the choice of unfired building materials, because unfired building materials are environmentally friendly building materials that can be recycled or naturally degraded after use without producing toxic substances or harming the environment. The use of unfired building materials in construction projects can help minimize the negative environmental impacts associated with the extraction, processing, transportation, installation, manufacture, disposal, reuse and recycling of raw materials in the construction industry.

Criterion 2 (TKKT4) – *"Familiarity of construction workers with the use of non-fired materials*": Currently, many construction workers are still accustomed to using traditional materials (fired materials), resulting in unfamiliarity with non-fired materials during construction. Therefore, guidance and training from the manufacturer is essential to ensure workers understand the correct techniques and construction procedures. Since the use of non-fired materials requires strict adherence to technical guidelines, training plays a crucial role in ensuring construction quality.

Criterion 3 (TKKT5) – *"Understanding of non-fired materials among investors, project management units, design consultants and contractors"*: During the design and construction process, investors, design offices, site managers, contractors and end users often still opt for conventional materials out of habit. As a result, the introduction of non-fired materials encounters difficulties due to a lack of comprehensive understanding of their types and methods of use. In addition, stakeholders such as investors, specifiers, construction managers and contractors have not proactively approached manufacturers for information on non-fired materials. This is mainly due to the lack of intermediary organizations such as building associations or regulatory bodies that could facilitate contacts and provide more comprehensive and accessible information.

Criterion 4 (CP3) – *"Construction costs of projects using non-fired materials during implementation":* Construction costs are an important factor influencing the decision to use non-fired materials. The public perception is that the use of non-fired materials is more expensive compared to traditional materials.

4. Discussions and recommendations

Based on the research findings, the author proposes several recommendations to promote the use of non-fired construction materials (NFCMs) in Binh Duong province. These proposed solutions focus on removing existing barriers, raising awareness among stakeholders, and creating favorable conditions in terms of policies, regulations, and technical support to promote the use of non-fired building materials in construction projects. The proposed solutions are categorized as follows:

Solution 1: Organize regular conferences and seminars on construction materials, especially on non-fired construction materials (NFCMs) to showcase their properties and new product types. This will help raise awareness among investors, design consultants, construction managers, contractors and consumers. In addition, media agencies should continue to promote the use of NFCMs to replace clay-fired bricks and thus contribute to energy saving and environmental protection.

Solution 2: Strengthen environmental awareness campaigns by displaying banners and slogans, and publishing content in provincial magazines, particularly emphasizing the environmental benefits of using NFCMs.

Solution 3: Issue incentive policies to attract investment in NFCM production using modern technologies that save natural resources and utilize recycled materials or alternative fuels. At the same time, implement strict regulations for NFCM production facilities that overexploit natural resources or cause environmental pollution.

Solution 4: Introduce support policies for NFCM manufacturers to provide training and skills development for workers, ensuring product quality and construction efficiency

Solution 5: Provide tax and financial incentives to NFCM producers such as tax deferral, tax reductions, or land- use fee exemptions to help lower production costs and improve competitiveness

Solution 6: Direct local construction authorities to issue guidelines for the use of NFCMs and share relevant technical information with all construction stakeholders.

Solution 7: Recommend that the Government and relevant Ministries study and implement preferential policies on taxes such as import tax on equipment and parts, corporate income tax, and VAT. In addition, establish preferential loan mechanisms through the Social Policy Bank to support both NFCM producers and end-users.

5. Conclusion

Based on the findings and discussions, the study concludes that while Binh Duong province has significant potential for the introduction of non-fired construction materials (NFCMs), there are still some challenges to overcome in practice. The government's push to replace traditional clay bricks with more sustainable NFCMs is in line with the province's rapid urbanization and growing demand for building materials. However, the successful integration of NFCMs into the construction industry largely depends on the perspectives and cooperation of key

stakeholders such as investors, design consultants, and contractors.

Despite the availability of NFCMs that meet technical standards, the choice of the most suitable material requires a thorough consideration of various factors, including technical specifications, environmental impact and socio-cultural context. In addition, it is crucial to build a strong consensus between all parties involved - investors, designers, contractors and regulators - to ensure that the use of sustainable materials is not only a legal requirement, but also industry-wide practice.

To address the current challenges and promote the use of NFCMs more effectively, it is recommended that policy makers focus on raising awareness, creating financial and technical incentives and encouraging collaboration between all stakeholders. The proposed solutions, including organizing seminars, offering tax incentives and facilitating the exchange of information, aim to create a more favorable environment for the widespread adoption of NFCMs.

Ultimately, the successful transition to NFCM in Binh Duong's construction sector requires a multi-faceted approach that combines regulatory enforcement, industry collaboration, technological innovation and continuous education and training of all stakeholders. In this way, the province can not only achieve its environmental and sustainability goals, but also pave the way for a more resilient and future-oriented construction industry.

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