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ARTICLES (PEER REVIEWED)

Assessing the Potential of Agri-Waste Coarse Aggregates for Sustainable Concrete Production in Ghana

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Abstract

The increasing adoption of alternative construction materials is central to advancing sustainability in the construction industry, particularly in developing countries, where agri-waste presents both an environmental challenge and an opportunity as a resource. This study examined the factors influencing the preparedness of construction professionals in Ghana to adopt agricultural-waste coarse aggregates (AWCA) for sustainable concrete production. Specifically, this study assessed professionals' knowledge and awareness of AWCA and their perceptions and intentions regarding its adoption. A structured questionnaire was administered to construction professionals, yielding 260 valid responses. The data were analysed using descriptive statistics and structural equation modelling (SEM) within the theory of planned behaviour framework. The results indicate that while respondents exhibited moderate awareness of AWCA, their technical understanding of material processing, testing requirements and performance standards was limited. Perceptions towards AWCA were generally cautious, with concerns regarding durability, contamination risks, client acceptance and the lack of local demonstration projects. SEM results showed that both knowledge and perception significantly influenced professionals' intention to adopt AWCA, with perception emerging as the stronger predictor. This study further identified major barriers to adoption, including the lack of

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standards, inadequate testing infrastructure, supply-chain challenges and limited policy support. These constraints persist despite the recognised environmental benefits of AWCA. This study concludes that improving AWCA adoption in Ghana requires targeted professional capacity-building initiatives, locally validated demonstration projects and clear regulatory guidelines.

Keywords

Agricultural Waste; Coarse Aggregates; Sustainable Construction; Adoption Intention; Theory of Planned Behaviour

Introduction

Ghana's construction industry contributes almost 15% of the national gross domestic product and is integral to economic growth, yet imposes significant environmental risks requiring urgent attention ([Frimpong et al., 2020](#)). This problem is no different when it comes to embracing sustainable concrete, as the industry primarily relies on traditional concrete manufacturing, a method recognised for its resource-intensive nature and substantial CO₂ emissions ([Agyekum et al., 2024](#)).

Agricultural waste such as palm kernel and coconut shell has emerged as a promising substitute for conventional aggregates ([Sangmesh et al., 2023](#)). Ghana is an agriculturally rich nation that generates substantial quantities of agricultural waste annually due to harvesting and processing, including coconut shells, palm kernel shells, cobs and other organic matter ([Nelson et al., 2021](#)). The potential transformation of these agricultural wastes into construction materials offers dual benefits: addressing waste management challenges while providing sustainable alternatives for the construction industry ([Chen et al., 2024](#)). However, despite the apparent advantages and availability of agricultural waste materials, their adoption in Ghana's construction industry remains limited primarily due to various technical, social and economic barriers that have not been thoroughly investigated from the perspective of construction professionals ([Anarfi et al., 2020](#)).

The construction industry has a role to play in achieving these goals ([Fei et al., 2021](#)). This study aligns with Sustainable Development Goal (SDG) 12 (responsible consumption), SDG 9 (industry, innovation and infrastructure) and SDG 11 (sustainable cities), as AWCA reduce the industry's reliance on traditional aggregates, advance construction innovation and contribute to affordable and environmentally responsible housing in Ghana ([Goubbran, 2019](#); [Fei et al., 2021](#)).

Despite the evident policy relevance of AWCA and the growing technical evidence base for their use, the factors that shape construction professionals' knowledge, perceptions and adoption intentions in the Ghanaian context have not been systematically examined. Understanding these behavioural and cognitive dimensions is essential, as material adoption in the construction industry ultimately depends not only on technical viability but also on the informed willingness of professionals to specify, supervise and advocate for new materials in practice. This study addresses that gap.

This study specifically aimed to (i) assess the construction professionals' knowledge and awareness of AWCA, (ii) examine their perception of AWCA adoption in the industry, (iii) analyse the major drivers and barriers of AWCA adoption and (iv) evaluate how knowledge and perception influence professionals' intention to adopt AWCA.

Literature review

GLOBAL AND GHANAIAAN CONTEXT OF ADOPTION OF AGRI-WASTE COARSE AGGREGATES

Globally, agricultural waste integration into concrete has advanced significantly, with Asian countries (such as Malaysia and India) and several European countries demonstrating commercial-scale adoption. Ghana,

despite being a leading agricultural nation, is yet to shift focus to AWCA adoption in the construction industry despite several research studies conducted by both academia and industry on this subject ([Sangmesh et al., 2023](#); [Oppon et al., 2025](#)). This clearly shows that Ghana can improve the promotion of such alternative materials if the right policy frameworks (PCF), continuous education and the promotion of more case studies are put in place to drive their adoption ([Ofori-Kuragu et al., 2016](#); [Soares et al., 2025](#)).

KNOWLEDGE AND AWARENESS OF AGRI-WASTE COARSE AGGREGATES

In Ghana, some construction professionals may be aware that there are agricultural waste aggregates that can be utilised in construction projects; however, studies have shown that there is no, or very little, knowledge of the implementation of appropriate testing, design, material handling and the utilisation of AWCA ([Addy et al., 2024](#); [Soares et al., 2025](#)). Across both developed and developing countries, formal curricula, structured professional training and industry-specific standards for AWCA remain largely absent, leaving practitioners to navigate material specification without adequate institutional support ([Addy et al., 2024](#); [Adebowale et al., 2025](#)). Studies have shown that there is little knowledge of appropriate testing procedures, material handling and mix design for AWCA among Ghanaian construction professionals. Within the theory of planned behaviour (TPB) framework, this knowledge deficit directly reduces perceived behavioural control, the key cognitive precursor to adoption intention ([Addy et al., 2024](#); [Soares et al., 2025](#)).

PERCEPTION OF UTILISING AGRI-WASTE COARSE AGGREGATES

The perceptions of construction experts regarding AWCA are influenced by complex socio-technical, economic and socio-cultural interdependencies. A common concern highlighted in the literature is uncertainty regarding the structural and durability performance of AWCA in construction. Industry professionals are still sceptical about the structural performance and durability, safety risks, and service life and load-bearing capacity of construction waste substitutes compared with traditional stones ([Oppon et al., 2025](#)). Concerns about safety and contamination also have an impact on perceptions. Agricultural residues may contain organic impurities, fine particles or even organic microbial contaminants, all of which may raise concerns about the safety and quality of the concrete, as well as workplace occupational health and safety ([Chen et al., 2024](#)). Stakeholders are also concerned about the safety of their equipment. Perception is also influenced by economic arguments. Despite AWCA being advocated based on their potential for cost savings, across several jurisdictions, processing, transportation, grading and even quality control have made the cost savings achieved by AWCA negligible ([Chen et al., 2024](#); [Ali et al., 2025](#)). Research has indicated that clients are often reluctant to accept materials identified as waste. The reluctance stems from clients' feeling that the materials are of inferior quality or from the fear of losing their reputation. This also inhibits professionals from choosing to incorporate AWCA formally into projects ([Abdulai et al., 2024](#)). The stigma continues to exist even if the advantage to the environment is recognised.

DRIVERS FOR ADOPTION OF AGRI-WASTE COARSE AGGREGATES

Drivers for AWCA adoption include environmental concerns, economic possibilities, technology availability and institutional influences. A primary concern expressed in the literature is the push to minimise the negative impacts of the concrete production cycle on the environment, particularly with the negative effects of ecological destruction from aggregate excavation ([Chen et al., 2024](#)). The inclusion of AWCA contributes to the circular economy by recycling agricultural waste into a raw material for the construction industry and by minimising the disposal of construction waste and the reliance on natural aggregates ([Islam et al., 2024](#)). Economic factors represent a second primary concern. In situations where agricultural waste is in surplus, AWCA can be an economically beneficial approach, especially in situations where there is a formalised

supply chain from agricultural waste processors to concrete producers ([Ali et al., 2025](#)). The situation is especially strengthened in Ghana, where there are high levels of production and low levels of use of palm kernel shells, coconut shells and other types of organic waste in the construction sector.

Also acting as catalysts for adoption are institutional and regulatory frameworks. Examples include government mandates and incentives, sustainability requirements and green-building certifications that promote the application of low-carbon construction materials ([Fei et al., 2021](#)). Where possible, industry standards and specifications give practitioners extra confidence and assurance that the consistency and safety of AWCA used in a structural application will reduce inherent risks. The use of appropriate equipment also increases adoption by providing improved quality and performance reliability, as well as accurate control and grading ([Maraveas, 2020](#)).

BARRIERS TO THE ADOPTION OF AGRI-WASTE COARSE AGGREGATES

The use of AWCA faces several hurdles, including the lack of skills regarding the processing, manipulation and use of agricultural waste additives as part of a sludge concrete binder ([Shafiqh et al., 2021](#)). This results in uneven and varied material performances, and in turn, the practitioners who lack the skills are constrained in their perceived behavioural control, which is necessary for adoption, as hypothesised in the TPB. One of the most notable constraints is the lack of comprehensive and well-defined testing. We establish standards and specifications to enhance stakeholder assurance and simplify material certification ([Mahmood et al., 2025](#)). This system should be enhanced. The absence of such systems causes difficulties in the assessment of appreciation and compliance with construction regulations on AWCA, as well as the estimation of resistance and longevity of the use of AWCA. The variability of agricultural waste characteristics and the scarcity of standardised supply chains increase these barriers in Ghana ([Boon & Anuga, 2020](#); [Chen et al., 2024](#)).

A pattern was confirmed by recent evidence from the West African context, where [Adebowale et al. \(2025\)](#) identified inadequate expertise, regulatory gaps and supply-chain fragility as the primary constraints on sustainable construction material adoption in developing economies, and [Oppon et al. \(2025\)](#) documented the limited penetration of agri-waste aggregate knowledge into Ghana's professional practice. Socio-cultural and market-level barriers also exert influence. A persistent negative perception of waste-based materials discourages both clients and practitioners, who may associate such materials with inferior quality or reputational risk ([Shooshtarian et al., 2020](#); [Galmarini et al., 2022](#)). In addition to institutional resistance stemming from quarry firms and established supply networks supportive of the ongoing domination of traditional aggregates, there is also opposition from industries that gain from the ongoing use of traditional aggregates ([Gupta et al., 2023](#)).

Economic barriers arise from the possible elimination of material expenses due to the negative cost benefits regarding processing, the inclusion of standardised aggregates and quality control, particularly in an undeveloped supply chain ([Chen et al., 2024](#)).

INTENTION TO ADOPT AGRI-WASTE COARSE AGGREGATES

Concerns over construction professionals' cognitive evaluations, normative influences and control dimensions in the industry manifest in their intent to use AWCA in their construction activities. The intent to adopt a practice has been well examined in the context of construction ([Anokye et al., 2024](#)). In situations where professionals have a low level of technical knowledge or understanding of the processing and performance of AWCA, the intent remains low due to low perceived behavioural control, one of the main constructs of the TPB ([Keong & Hirst, 2010](#)).

Research in several developing construction market countries, including Ghana, has shown that intent to adopt is stronger when the perception of an innovation is positive. Understanding the use of the innovation

in a construction context, as well as its environmental and economic value, positively influences the intent ([Ahinkorah et al., 2023](#)). Conversely, negative perceptions, such as contamination fears, durability concerns or stigma associated with waste-based materials, undermine professionals' confidence and, in turn, weaken adoption intention ([Mohammed et al., 2023](#)).

Research has suggested that professionals can move towards AWCA adoption when regulatory standards and supply-chain infrastructure are clearly established ([Godfrey et al., 2012](#)). Project demonstrations, pilot programmes and local performance reports help to minimise perceived risks by improving observability and compatibility, which are significant dimensions of the diffusion of innovations (DoI) theory ([Ojedokun et al., 2022](#)). [Figure 1](#), as adopted from [Hasbullah et al. \(2016\)](#), shows the sequence of TPB.

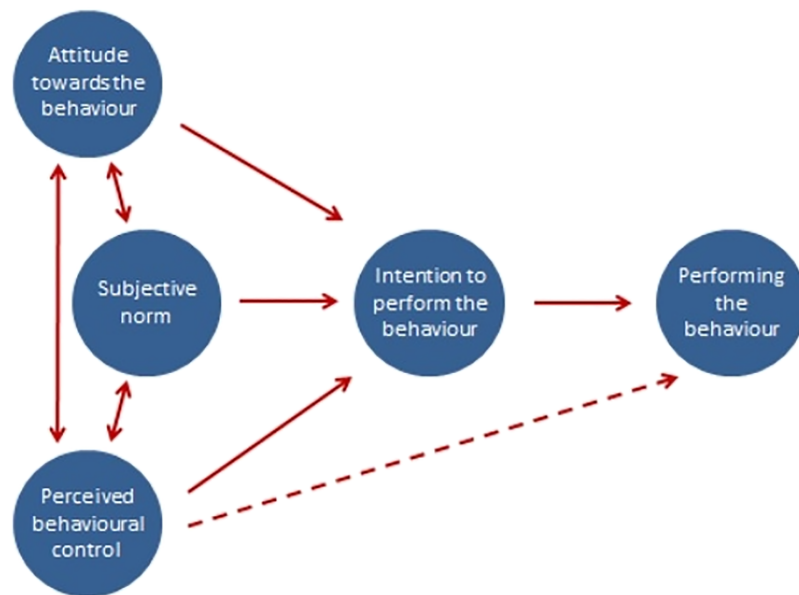


Figure 1. Theory of planned behaviour ([Hasbullah et al., 2016](#)).

When the TPB and DoI are used together, they provide a complementary analytical framework: the TPB explains why professionals intend (or fail) to adopt through the cognitive antecedents of attitude, subjective norms and perceived behavioural control; the DoI explains when and how that intention translates into system-level uptake through the innovation attributes of relative advantage, compatibility, observability, trialability and complexity ([Bonke & Musshoff, 2020](#); [Jampala & Shivnani, 2024](#)). The review of literature suggests that the intention to adopt AWCA in construction stems from evidence of the interaction of knowledge sufficiency, favourable and supportive institutions, and confidence. If Ghana aims to increase AWCA adoption, there is an imminent need to develop intervention mechanisms such as policies, demonstrative interventions and certification interventions in the construction sector.

Methodology

This research used a descriptive survey design to investigate the use of AWCA in the construction industry of Ghana. A survey was used to evaluate the knowledge, perception, behavioural intention, drivers, barriers and attitude of construction practitioners towards the use of AWCA. The survey instrument was structured into five parts: demographic profile, knowledge and awareness of AWCA, perception of technical and social performance, drivers and barriers, and intention to adopt the use of AWCA. Responses were examined using a 5-point Likert scale. A pilot study was conducted with 30 construction professionals who were not

included in the final survey. Cronbach's alpha score was 0.80, which exceeded the recommended 0.70 across all constructs ([Agyemang et al., 2026](#)). Based on their feedback, three items were removed, and two items were rewritten for clarity. The revised instrument was confirmed suitable for the main survey. Data were collected from construction professionals through online and face-to-face surveys using purposive sampling. Respondents included engineers, quantity surveyors, architects, construction managers and technologists from industry and academia.

Respondents were selected based on their (i) educational background in a built environment discipline and (ii) active professional practice in the Ghanaian construction industry and membership of a recognised professional body in the construction industry. Students without practical experience and professionals outside Ghana were excluded. A target of 331 professionals was set using the [Krejcie and Morgan \(1970\)](#) formula. In all, 260 valid responses were received, which exceeded the minimum of 200 participants set for structural equation modelling (SEM) analysis ([Hair et al., 2010](#)). The shortfall in relation to the target population is acknowledged as a limitation, driven by the difficulty of data collection in the construction industry. All participants provided informed consent; participation in the survey was voluntary and anonymous, with no personal information collected. Collected data were stored on a password-secured hard drive, and physical questionnaires were locked in a cabinet. Research integrity was maintained through transparent data recording, accurate reporting and full attribution of all cited sources.

Data analysis was conducted using SPSS 26 and SPSS AMOS for both descriptive analysis and inferential analysis (SEM). The SEM was used to validate constructs and test hypothesised relationships between knowledge, perception and adoption intention. Two separate bivariate SEM models examined the knowledge and awareness (KA) to intention (I) and perception (P) paths independently, which is consistent with the TPB's treatment of attitude and perceived behavioural control (PBC) as separate antecedents of intention ([Ajzen, 1991](#); [Bryne, 2010](#); [Kline, 2016](#)). The near-identical R^2 values of 0.45 and 0.448 confirm complementary rather than redundant predictors. For future research, we recommend an integrated model.

Results and discussion

The results of this study are presented and discussed in this section, beginning with the respondents' demographic profile and construction professionals' perception of AWCA adoption.

[Table 1](#) presents the respondents profile indicating their level of education, professional background, field of work, their professional body, and level of experience.

KNOWLEDGE AND AWARENESS OF AWCA

The analysis studied the exposure of the respondents to literature, case studies and technical training regarding the use of agricultural waste aggregates. Based on the assessment of the presented factors, the section recommends using the mechanics of education to raise the skill level of field practitioners and to stimulate increased use and application in the field considered. According to the findings in [Table 2](#), the respondents reported a moderate level of knowledge of AWCA, with the highest scores on reading-related exposure (mean = 3.16) and AWCA engagement (mean = 3.29). However, the respondents reported low familiarity with preliminary standards (mean = 2.64), testing protocols (mean = 2.50), mix design (mean = 2.46) and handling aspects (mean = 2.65). Training exposure was notably low (mean = 2.31), indicating limited formal capacity-building opportunities. [Table 2](#) presents the ranking of the variables under knowledge and awareness.

This pattern hints at a general knowledge gap in Ghana's construction industry, where awareness of a material or technology in its early stages is far ahead of professionals' experience in utilising it. Similar trends have been documented in India, Kenya and Malaysia, where agricultural waste-based materials are

Table 1. Respondent demographic profile.

Respondent profile	Frequency	Percentage
Education		
Doctorate degree	8	3.08%
Master's degree	104	40.00%
Bachelor's degree	115	44.23%
Others (Diploma, Higher National Diploma and professional certificates)	33	12.69%
Profession		
Civil engineers	106	40.80%
Architects	25	9.60%
Quantity surveyors	77	29.60%
Construction managers	40	15.40%
Others (project managers, construction engineers and construction technologists)	12	4.60%
Field of work		
Construction	192	73.85%
Academia	12	4.62%
Academia and construction	52	20.00%
Others (rail transportation, architecture, engineering and construction industry and utility company)	4	1.53%
Professional body		
Ghana Institution of Engineering and Institution of Engineering and Technology	129	49.62%
Ghana Institute of Architects	25	9.62%
Ghana Institute of Surveyors	87	33.36%
Ghana Institute of Construction	19	7.40%
Level of experience		
Below 6 years	78	30.00%
6–10 years	70	26.90%
11–15 years	47	18.10%
16–20 years	28	10.80%
Above 20 years	37	14.2%

conceptually known but practically unfamiliar due to the absence of training in their use ([Mbadugha et al., 2022](#)). The observed knowledge deficit directly undermines professionals' perceived behavioural control, reducing confidence in specifying or supervising AWCA use ([Addy et al., 2024](#)). Capacity building through updating of curricula and standardised technical manuals is essential. Without strengthening technical literacy, adoption will remain a mirage despite growing awareness. [Table 3](#) presents the unidimensionality and reliability of knowledge and awareness.

The exploratory factor analysis (EFA) used maximum likelihood varimax rotation yielded a Kaiser-Meyer-Olkin (KMO) of 0.935 and Bartlett's sphericity of $p < 0.000$. All 12 items loaded onto a single factor. Cronbach's alpha of 0.92 confirmed a high internal consistency. Confirmatory Factor Analysis (CFA) confirmed an acceptable fit with the following values: Comparative Fit Index (CFI) = 0.927, Normed Fit Index (NFI) = 0.906, Root Mean Square Error of Approximation (RMSEA) = 0.041, Root Mean Square Residual (RMR) = 0.0036, Goodness-of-Fit- Index (GFI) = 0.941 and Parsimonious Normed Fit Index

Table 2. Knowledge and awareness (KA).

SN	Factors	Mean	Standard deviation	Rank
KA1	I am aware of the use of agricultural waste as coarse aggregates in concrete production.	3.29	1.223	1
KA2	I am aware of case studies demonstrating the use of agricultural waste aggregates in the production of concrete for construction projects.	3.19	1.212	2
KA3	I am aware of specific agricultural wastes that are used as coarse aggregates.	3.18	1.216	3
KA4	I have read studies on the use of agricultural-waste coarse aggregates for construction.	3.16	1.170	4
KA5	I am aware of how agricultural waste aggregates are sourced, handled and processed into coarse aggregates.	2.65	1.154	5
KA6	I am familiar with standards and specifications for agricultural-waste coarse aggregates in concrete production.	2.64	1.097	6
KA7	I am knowledgeable about the requirements for using agricultural waste as coarse aggregate.	2.55	1.189	7
KA8	I know of equipment used to handle agricultural-waste coarse aggregates on construction sites.	2.52	1.284	8
KA9	I am familiar with the testing procedures to assess the agricultural-waste coarse aggregate concrete performance.	2.50	1.238	9
KA10	I understand how to design concrete mixes with agricultural waste aggregates.	2.46	1.157	10
KA11	I understand how the properties of agricultural-waste coarse aggregates are tested.	2.45	1.129	11
KA12	I have received training or education on agricultural-waste coarse aggregates.	2.31	1.220	12

(Source: field data, 2025)

(PNFI) = 0.604. The chi-square was treated as a descriptive index given its sensitivity to sample size (Kline, 2005). Table 4 presents the data on the robust fit for index for knowledge and awareness.

Table 5 presents the factor loadings, standard errors and test results for the final 12-item model of KA. All the correlation values were below 1.00, and all the p-values were less than 0.05. This shows that the results are statistically significant and acceptable. The item with the highest standardised coefficient was KA1, with a value of 0.898, making it the strongest indicator of the construct.

The factor loadings ranged from 0.620 (KA12) to 0.898 (KA1), with high R^2 values indicating that the construct explains a substantial portion of the variation in the items. This means the items are good measures of the construct.

Table 3. Unidimensionality and reliability of knowledge and awareness (KA).

	KA	Corrected item-total correlation	Squared multiple correlation	Cronbach's alpha if item deleted	Cronbach's alpha
I know of equipment used to handle agricultural-waste coarse aggregates on construction sites	0.898	0.682	0.633	0.951	0.952
I am familiar with the testing procedures to assess the agricultural-waste coarse aggregate concrete performance	0.878	0.699	0.702	0.950	
I understand how the properties of agricultural-waste coarse aggregates are tested	0.877	0.681	0.667	0.951	
I understand how to design concrete mixes with agricultural waste aggregates	0.871	0.703	0.697	0.950	
I am knowledgeable about the requirements for using agricultural waste as coarse aggregate	0.866	0.816	0.722	0.947	
I am aware of how agricultural waste aggregates are sourced, handled and processed into coarse aggregates	0.848	0.750	0.695	0.949	
I am familiar with standards and specifications for agricultural-waste coarse aggregate use in concrete production	0.816	0.819	0.774	0.946	
I have received training or education on agricultural-waste coarse aggregates	0.802	0.821	0.729	0.946	
I am aware of specific agricultural wastes that are used as coarse aggregates	0.640	0.810	0.781	0.947	
I am aware of the use of agricultural waste as coarse aggregates in concrete production	0.631	0.816	0.781	0.946	

Table 3. continued

	KA	Corrected item-total correlation	Squared multiple correlation	Cronbach's alpha if item deleted	Cronbach's alpha
I have read studies on the use of agricultural-waste coarse aggregates for construction	0.624	0.809	0.809	0.947	
I am aware of case studies demonstrating the use of agricultural waste aggregates in the production of concrete for construction projects	0.620	0.837	0.832	0.946	

[Source: field data, 2025]

Table 4. Robust fit index for knowledge and awareness (KA) attributes.

Fit index	Cut-off value	Estimate	Comment
S-B χ^2		2.983	
df	≥ 0	54	Acceptable
CFI	≥ 0.90 , acceptable ≥ 0.95 , good fit	0.905	Acceptable
Parsimony comparative fit index (PCFI)	< 0.80	0.659	Good fit
RMSEA	$< .08$	0.027	Acceptable
RMSEA 95% CI	0.00–0.08, “good fit”	0.007–0.033	Acceptable
NFI	> 0.90 , “good fit”	0.911	Good fit
Incremental fit index (IFI)	> 0.90 , “good fit”	0.906	Good fit
PNFI	< 0.80	0.648	Good fit
RMR	< 0.05 , “good fit”	0.047	Acceptable
GFI	< 0.90 , “good fit”	0.945	Good fit

[Source: field data, 2025]

PERCEPTION OF AWCA ADOPTION

Table 6 shows that the respondents had feasible but mildly optimistic assessments of AWCA's sustainability. Evaluation concerns about client objections (mean = 3.96, SD = 1.007) and the necessity for strict quality control (mean = 3.92, SD = 1.168) point to a lack of robust performance validation, suggesting a prominent and persistent challenge. The absence of pilot demonstration projects (mean = 3.72, SD = 1.140) points to the same persistent challenge and demonstrates the presence of uncertainty regarding DoI theory's emphasis on the observability of innovations. Likely sources of contaminants (mean = 3.31, SD = 1.058) and potential sources of health concerns (mean = 3.32, SD = 1.080) represent trade-offs. A perception that the cost savings brought by AWCA (mean = 3.53, SD = 0.992) may be limited poses a restraint on the

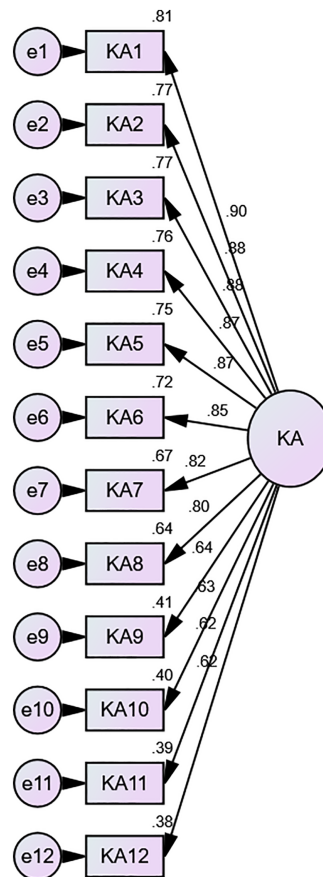


Figure 2. CFA model for knowledge and awareness (KA).

respondents' enthusiasm and confidence about AWCA's potential to be economically competitive, at least from a practical viewpoint.

The data analyses show that respondents' perceptions were influenced by risk aversion, which is a common global characteristic within the construction industry. When evaluating substitutes, construction professionals prioritise client concern, reliability, structure, safety/performance and durability, which they do not perceive as uncertain or safe for AWCA, given evidence, or the lack thereof, in Ghana. These are correlated with the principles of the DoI theory, which perceives AWCA as an abstract, untested and unproven innovation and views trialability and perceived job cost as more important than client concern. AWCA need evidence of local success to shift conventional material preferences ([Amede et al., 2025](#)).

The concern for client resistance is consistent with the results of several studies ([Shooshtarian et al., 2020](#)) in Ghana and South Africa that found that the social construction of stigma, which is observed in these studies, centred on the use of "waste-based" materials, which discourages both clients and construction professionals from adopting the remaining sustainable alternatives that are available. This emphasises that AWCA adoption is constrained not only by technical performance but also by socio-cultural perceptions ([Galmarini et al., 2022](#)). Researchers, material producers and regulatory agencies must collaborate to create verifiable evidence of AWCA performance under Ghanaian climatic and construction conditions. Perception improvement will yield substantial benefits later, as SEM results indicate that perception is a stronger predictor of intention than knowledge. [Table 7](#) presents the unidimensionality and reliability results for perception.

Table 5. Factor loading and p-value of knowledge and awareness (KA).

Hypothesised relationships (path)	Unstandardised coefficient (λ)	Standardised coefficient (λ)	p-Value	R ²	Significant at 5% level
KA1 $\leftarrow$ KA	1.000	0.898	0.00	0.807	Yes
KA2 $\leftarrow$ KA	0.943	0.878	0.00	0.771	Yes
KA3 $\leftarrow$ KA	0.858	0.877	0.00	0.768	Yes
KA4 $\leftarrow$ KA	0.874	0.871	0.00	0.759	Yes
KA5 $\leftarrow$ KA	0.893	0.866	0.00	0.749	Yes
KA6 $\leftarrow$ KA	0.848	0.848	0.00	0.718	Yes
KA7 $\leftarrow$ KA	0.776	0.816	0.00	0.665	Yes
KA8 $\leftarrow$ KA	0.848	0.802	0.00	0.643	Yes
KA9 $\leftarrow$ KA	0.675	0.640	0.00	0.409	Yes
KA10 $\leftarrow$ KA	0.669	0.631	0.00	0.398	Yes
KA11 $\leftarrow$ KA	0.633	0.624	0.00	0.390	Yes
KA12 $\leftarrow$ KA	0.652	0.620	0.00	0.385	Yes

[Source: field data, 2025]

The EFA using maximum likelihood varimax rotation yielded a KMO of 0.850 and Bartlett's sphericity of $p < 0.000$. Three items with loadings below 0.50 were removed. Cronbach's alpha ranged from 0.80 to 0.85, confirming a high internal consistency. The CFA confirmed an acceptable fit with the following values: CFI = 0.927, NFI = 0.906, RMSEA = 0.041, RMR = 0.0036, GFI = 0.941 and PNFI = 0.604. The chi-square was treated as a descriptive index given its sensitivity to sample size (Kline, 2005). Table 8 presents the robust fit index for perception.

Table 9 shows the correlation values, standard errors and test statistics for the final 10-indicator model. All correlation values were less than 1.00, and all p-values were less than the significance level of 0.05 and showed the appropriate signs. The estimates were therefore deemed both reasonable and statistically significant. The parameter with the highest standardised coefficient was the indicator variable P1, with a parameter coefficient of 0.797.

The factor loadings ranged from 0.532 (P7) to 0.797 (P1), with all the estimates statistically significant ($p < 0.000$). The high R² value indicated that the construct explains a substantial portion of the variation in the items, which means the items are good measures of the construct.

DRIVERS FOR ADOPTING COARSE AGGREGATES OF AGRICULTURAL WASTE FOR CONCRETE PRODUCTION

Table 10 shows the key drivers for adopting agricultural waste as coarse aggregates in concrete production. Partnership between waste and concrete producers (mean = 4.02, SD = 0.0913) and cost reduction (mean = 4.00, SD = 0.959) were the primary motivators. Another top driver that can increase the adoption rate was successful demonstrations of AWCA (mean = 3.97, SD = 0.948). Environmental sustainability was another key driver, with "adopting agri-waste coarse aggregates will help reduce waste generation and environmental impact" scoring high (mean = 3.94, SD = 1.033). Corporate sustainability initiatives scored a mean of 3.93

Table 6. Perception of agricultural-waste coarse aggregate (AWCA) adoption (PE).

SN	Factors	Mean	Standard deviation	Rank
PE1	Client's objections may limit the ability to adopt waste aggregates	3.96	1.007	1
PE2	Quality control measures are needed for agricultural-waste coarse aggregates	3.92	1.168	2
PE3	There is a lack of demonstration projects that have used agri-waste coarse aggregates	3.72	1.140	3
PE4	The cost savings from agricultural waste aggregates are likely to be marginal	3.53	0.992	4
PE5	There is a negative stigma associated with the use of any waste	3.52	1.053	5
PE6	Agricultural waste aggregates may have performance issues	3.40	1.029	6
PE7	Using agri-waste coarse aggregate may pose health risks if not handled properly	3.32	1.080	7
PE8	Agricultural-waste coarse aggregates may introduce contaminants into the concrete produced	3.31	1.058	8
PE9	The negative perception that these agri-waste coarse aggregates may have an impact on the moving parts of the concrete mixers or concrete shooters/trucks	3.12	1.014	9
PE10	Agricultural-waste coarse aggregates meet structural and durability requirements and perform better as a substitute for conventional aggregates	3.07	0.958	10

(Source: field data, 2025)

(SD = 0.970) as “corporate bodies who want their facilities classified as green can incorporate agri-waste coarse aggregates”.

The results show that the use of agricultural waste as coarse aggregates is mostly affected by economic incentives and the degree of institutional cooperation. Collaboration between waste processors and concrete manufacturers is noted as the main driver, showcasing the necessity of effective “real” supply-chain links for innovative materials ([Herold & Marzantowicz, 2023](#)). This is consistent with previous studies that have demonstrated the importance of inter-sectorial cooperation in the use of substitute building materials ([Danvers et al., 2023](#)). In the case of Ghana, agricultural waste is effective for the cheaper construction of an agricultural concrete structure because of the economic incentives. Enhanced environmental sustainability is a prominent motivator, as using agricultural waste reduces the burden placed on the landfill and helps achieve the goals of the circular economy ([Ghisellini et al., 2016](#)). Government incentives and standards are crucial for long-term scaling, as well as for demonstration projects, to give practitioners confidence in utilising AWCA.

Table 7. Unidimensionality and reliability of perception (P).

	p	Corrected item-total correlation	Squared multiple correlation	Cronbach's alpha if item deleted	Cronbach's alpha
Client's objections may limit the ability to adopt waste aggregates	0.770	0.373	0.249	0.851	0.850
There is a lack of demonstration projects that have used agri-waste coarse aggregates	0.723	0.534	0.336	0.838	
Agricultural waste aggregates may have performance issues	0.690	0.634	0.454	0.829	
There is a negative stigma associated with the use of any waste	0.603	0.563	0.488	0.835	
Using agri-waste coarse aggregate may pose health risks if not handled properly	0.598	0.552	0.461	0.836	
Agricultural-waste coarse aggregates may introduce contaminants into the concrete produced	0.592	0.532	0.335	0.838	
Quality control measures are needed for agricultural-waste coarse aggregates	0.576	0.455	0.273	0.844	
The negative perception that these agri-waste coarse aggregates may have an impact on the moving parts of the concrete mixers or concrete shooters/trucks	0.575	0.550	0.362	0.836	
The cost savings from agricultural waste aggregates are likely to be marginal					
Agricultural-waste coarse aggregates meet structural and durability requirements and perform better than conventional aggregates					

[Source: field data]

Table 8. Robust fit index for perception (P).

Fit index	Cut-off value	Estimate	Comment
S-B χ^2		3.047	
df	≥ 0	14	Acceptable
CFI	≥ 0.90 , acceptable ≥ 0.95 , good fit	0.927	Acceptable
PCFI	< 0.80	0.618	Good fit
RMSEA	< 0.08	0.041	Acceptable
RMSEA 95% CI	0.00–0.08, “good fit”	0.020–0.051	Acceptable
NFI	> 0.90 , “good fit”	0.906	Good fit
IFI	> 0.90 , “good fit”	0.928	Good fit
PNFI	< 0.80	0.604	Good fit
RMR	< 0.05 , “good fit”	0.036	Acceptable
GFI	> 0.90 , “good fit”	0.941	Good fit

[Source: field data, 2025]

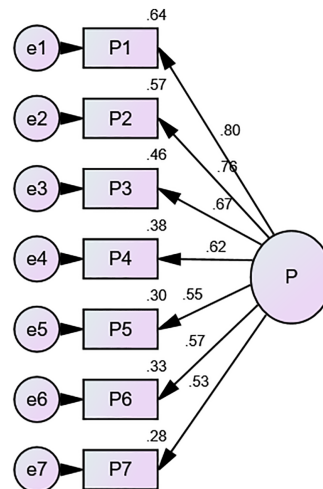


Figure 3. CFA model for perception (P).

BARRIERS TO AWCA ADOPTION

Table 11 shows barriers to using agricultural waste as coarse aggregates for concrete production. Major obstacles included limited knowledge, inadequate testing standards (mean = 4.09, SD = 0.898) and inadequate expertise (mean = 4.15, SD = 0.935). The need for expensive equipment (mean = 4.06, SD = 0.926) and difficulties in handling aggregates (mean = 3.98, SD = 0.940) were also significant barriers. The absence of a regulatory framework (mean = 4.03, SD = 0.948) indicates a need for policies to support adoption, while opposition to the use of agricultural waste by the industry (mean = 3.91, SD = 0.948) reflects concerns for the economic implications for the industry.

Table 9. Factor loading and p-value of perception (P).

Hypothesised relationships (path)	Unstandardised coefficient (λ)	Standardised coefficient (λ)	p-Value	R ²	Significant at 5% level
P1 $\leftarrow$ P	1.000	0.797	0.00	0.635	Yes
P2 $\leftarrow$ P	1.076	0.758	0.00	0.574	Yes
P3 $\leftarrow$ P	0.866	0.675	0.00	0.455	Yes
P4 $\leftarrow$ P	0.809	0.616	0.00	0.380	Yes
P5 $\leftarrow$ P	0.738	0.548	0.00	0.300	Yes
P6 $\leftarrow$ P	0.836	0.574	0.00	0.330	Yes
P7 $\leftarrow$ P	0.672	0.532	0.00	0.283	Yes

(Source: field data, 2025)

Despite the growing interest, the use of agricultural waste as coarse aggregate continues to face perceptual and logistical barriers. There is a negative perception of waste-based construction building materials that diminishes the trust of both professionals and the public. This is an important indicator of the need for more educational and awareness activities ([Shooshtarian et al., 2020](#)). The inconsistent supply and variability of waste also make it difficult to integrate them into concrete manufacturing. Significant obstacles are posed by equipment; the processing of agricultural waste requires specialised crushing and handling technologies ([Badraddin et al., 2021](#); [Wang et al., 2021](#)).

Without investment of this nature, it will be difficult to achieve standards for a reasonably uniform material, which may result in the concrete losing its quality. The market's slow adoption is the result of both institutional resistance and lengthy administrative processes. In the absence of clearly defined national standards and certification schemes, practitioners also adopt a wait-and-see approach ([Pacheco et al., 2023](#)). These issues undermine market trust and heighten concerns about performance predictability.

INFLUENCE OF KNOWLEDGE AND PERCEPTION ON INTENTION TO ADOPT AWCA

The last objective of this study was to examine how knowledge and perception influenced adoption intention, which were operationalised as two separate bivariate SEM models within the TPB framework. The results, shown in Figures 4 and 5 and Tables 12 and 13, attempt to clarify the psychological drivers of AWCA adoption in the construction industry in Ghana.

INFLUENCE OF KNOWLEDGE ON INTENTION TO ADOPT AWCA

The SEM in AMOS was used to examine the effect of KA on intentions (I) to adopt AWCA. We first confirmed that the model fit the provided values within an acceptable range, as recommended by [Hu and Bentler \(1999\)](#). The sample data yielded an S-B χ^2 of 3.519 with 274 degrees of freedom (df), corresponding to a p-value of 0.0000. This chi-square value indicated that the departure of the sample data from the postulated model was significant, suggesting a good fit of the model with respect to the effect of KA on intentions (I) to AWCA adoption. This also means that the postulated model adequately describes the sample data.

The statistical analysis shown in [Table 12](#) examines the relationship between KA and intentions (I) regarding the adoption of agricultural waste as coarse aggregates in concrete production. The results indicate a significant positive relationship between these two constructs, with a standardised coefficient of 0.234 and

Table 10. Drivers (DV).

SN	Drivers	Mean	Standard deviation	Rank
DV1	Partnership between waste processors and concrete producers	4.02	0.913	1
DV2	The desire to reduce the cost of concrete production	4.00	0.959	2
DV3	Successful demonstrations and case studies on the use of agricultural-waste coarse aggregates	3.97	0.948	3
DV4	Adopting agri-waste coarse aggregates will help the construction industry reduce its waste generation and reduce the negative impact on the environment	3.94	1.033	4
DV5	Corporate bodies that want to have their facilities classified as green can incorporate agri-waste coarse aggregates into their construction to help them achieve sustainability goals	3.93	0.970	5
DV6	Equipment and technologies to process agricultural waste into aggregates	3.90	0.964	6
DV7	Agri-waste aggregates are suitable substitutes for conventional aggregates if they can meet all the standards set out for aggregates used for concrete production	3.88	0.997	7
DV8	Increased client demand for agri-waste coarse aggregates will enhance their adoption	3.86	1.019	8
DV9	Government incentives and policies to increase the use of agricultural-waste coarse aggregates	3.84	0.931	9
DV10	Standards and specifications for the use of agricultural waste aggregates	3.75	0.953	10
DV11	The seasonal availability of agri-waste coarse aggregates for concrete production	3.67	1.108	11

[Source: field data, 2025]

a p-value of 0.000, well below the 0.05 threshold. This suggests that knowledge and awareness statistically influenced respondents' intention to adopt agricultural waste aggregates.

The standardised coefficient (0.234) indicated a positive but weak association between KA and I. While knowledge and awareness shape intentions, other factors may also significantly influence adoption decisions. The unstandardised coefficient of 0.165 indicates that the intention to adopt AWCA increases by 0.165 units per unit increase in knowledge. The R^2 value of 0.450 indicates that knowledge explains 45% of the variance in intention, suggesting that factors such as benefits, regulations or costs may influence adoption intentions.

The significant relationship (p-value = 0.000) indicates that knowledge and awareness influence intentions, underscoring the role of education in understanding the aggregate benefits of agricultural waste. Industry workshops could strengthen adoption intentions, although awareness alone may not drive widespread adoption, given the low standardised coefficient. While basic awareness of AWCA exists

Table 11. Barriers to agricultural-waste coarse aggregate (AWCA) adoption (BR).

SN	Barrier	Mean	Standard deviation	Rank
BR1	The inadequate expertise in the use of agri-waste coarse aggregates in construction projects	4.15	0.935	1
BR2	Insufficient testing and standards on the use of agricultural-waste coarse aggregates	4.09	0.898	2
BR3	The need for special equipment and facilities to process agricultural waste in large quantities	4.06	0.926	3
BR4	Lack of policies, standards and regulations on the use of agricultural-waste coarse aggregate	4.03	0.948	4
BR5	Challenges associated with the handling and processing of agri-waste coarse aggregates	3.98	0.940	5
BR6	There is a lack of data on the performance history of agri-waste coarse aggregates used for projects over the years	3.96	0.956	6
BR7	The lack of and inconsistent seasonal supply of agri-waste coarse aggregates	3.95	0.925	7
BR8	The negative perception of the use of agri-waste coarse aggregates	3.93	0.986	8
BR9	Resistance from industries benefiting from the use of conventional aggregates	3.91	0.948	9
BR10	Managing variability and multiple waste sources	3.85	0.925	10
BR11	Increased testing and quality control measures on the use of agricultural-waste coarse aggregates	3.81	1.069	11
BR12	Cost implications of the adoption of agricultural-waste coarse aggregates	3.80	1.086	12
BR13	Health concerns associated with the use of agricultural-waste coarse aggregates	3.65	1.049	13

(Source: field data, 2025)

among Ghanaian construction professionals, technical knowledge remains insufficient. The survey revealed moderate awareness of the literature (mean scores of 3.2–3.3), but technical aspects, such as testing and equipment handling, scored below 2.6. This gap between awareness and technical proficiency mirrors the development of contexts ([Islam et al., 2024](#)).

Construction professionals require knowledge of AWCA performance and standards to specify with confidence; without this, adoption intention remains constrained by low perceived behavioural control. Academia and industry must collaborate to spread AWCA knowledge through training and updated curricula ([Addy et al., 2024](#); [Soares et al., 2025](#)).

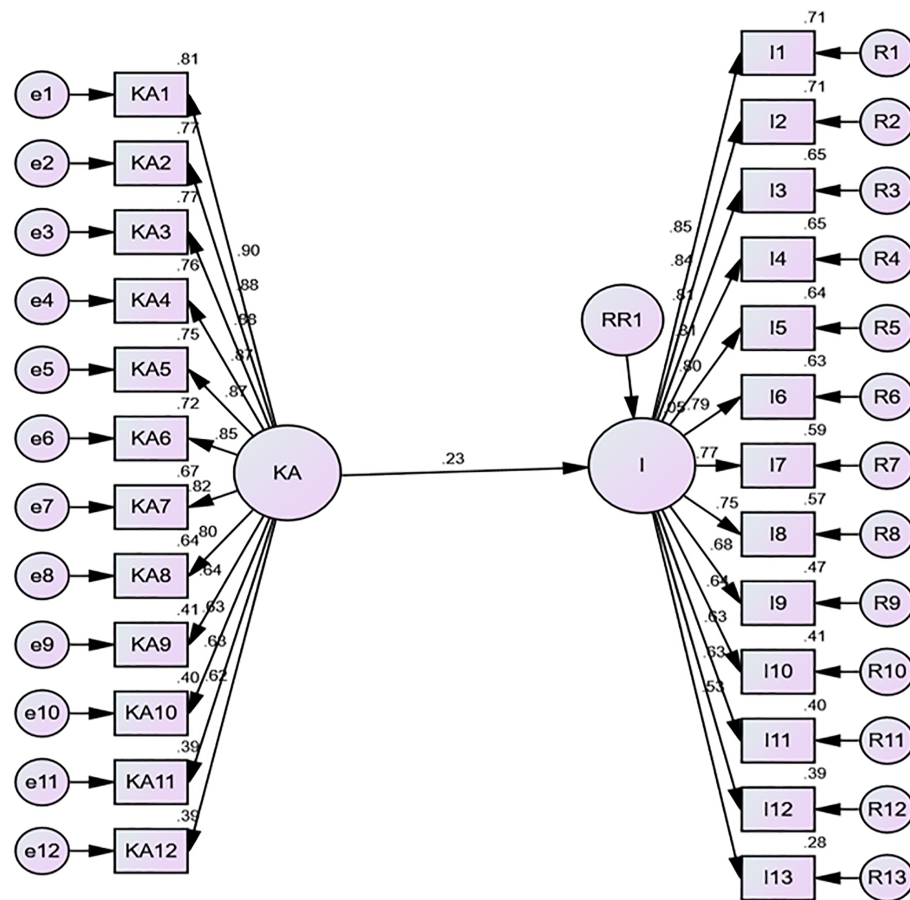


Figure 4. Structural equation modelling for the effect of knowledge and awareness (KA) on intentions (I) of agricultural-waste coarse aggregate (AWCA) adoption.

Table 12. Factor loading and p-value of the effect of knowledge and awareness (KA) on intentions (I) to adopt agricultural-waste coarse aggregate (AWCA).

Hypothesised relationship (path)			Unstandardised coefficient (λ)	Standardised coefficient (λ)	p-Value	R ²	Significant at 5% level
I	←	KA	0.165	0.234	0.000	0.450	Yes

[Source: field data, 2025]

INFLUENCE OF PERCEPTION ON INTENTION TO ADOPT AWCA

The perceptions of AWCA are neither positive nor negative, but they indicate a willingness to adopt, provided there is more solid empirical evidence, more obvious standards and better awareness of clients. As is common with research across the globe, issues over durability, safety and acceptance have a great impact on the readiness of professionals to use alternative aggregates. The descriptive analysis of the intention construct reveals moderate yet apprehensive behavioural preparedness. Although respondents recognise the potential of AWCA in terms of sustainability, there is still hesitation because of uncertainty about performance reliability and standardisation. This trend demonstrates the relevance of considering the interplay between knowledge and perceptions to influence the adoption intention in the TPB.

The SEM in SPSS AMOS was used to examine the effect of perception (P) on intention (I), as shown in Figure 5. The model fits were confirmed to be within an acceptable range, as recommended by Hu and Bentler (1999). The sample data yielded an S-B χ^2 of 3.943 with 169 degrees of freedom (df), $p = 0.0000$. This chi-square value indicated a significant departure from the postulated model, suggesting a good fit for the effect of perception (P) on intention (I) and adequately describing the sample data.

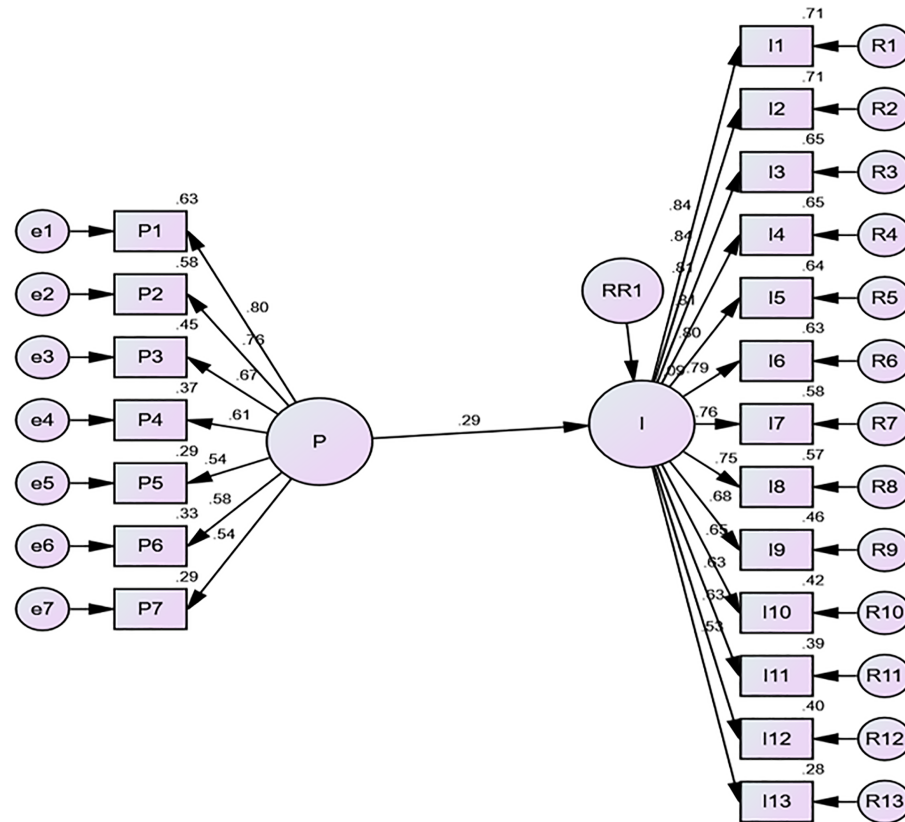


Figure 5. Structural equation modelling (SEM) for the effect of perception (P) on intention (I) to agricultural-waste coarse aggregate (AWCA) adoption.

Table 13 shows the relationship between perception (P) and intention (I) regarding the adoption of agricultural waste as coarse aggregate in concrete production. The standardised coefficient ($\lambda = 0.295$) indicates a positive but relatively weak relationship between perception and intention. This suggests that, while perception influences the intention to adopt agricultural waste aggregates, other factors may contribute significantly to the decision-making process.

Table 13. Factor loading and p-value of the effect of perception (P) on intention (I).

Hypothesised relationship (path)			Unstandardised coefficient (λ)	Standardised coefficient (λ)	p-Value	R ²	Significant at 5% level
I	f	P	0.299	0.295	0.000	0.448	Yes

[Source: field data, 2025]

The unstandardised coefficient (0.299) shows that for every unit increase in perception, intention increased by 0.299 units. This relationship is statistically significant (p -value = 0.000, below the 0.05 threshold), confirming that the effect is not due to random chance. The R^2 value of 0.448 indicates that perception accounts for 44.8% of the variance in intention, suggesting that factors such as regulatory policies, financial incentives and technological feasibility may also shape intention. The positive views of agricultural waste aggregates increase adoption intentions, although the effect size is small, indicating that perceptions alone cannot be used to promote adoption. Integration intention can be supported by policy support, demonstrations and cost–benefit analyses ([Jin et al., 2017](#)).

Summary of findings and discussion

Consistent with the TPB, these technical deficits weaken perceived behavioural control, thereby reducing professionals' confidence in using AWCA in practice. Prior studies have indicated that awareness alone rarely drives adoption unless supported by standards, accredited training and structured demonstration programmes ([Langen et al., 2021](#)).

The findings further show that professionals' acceptance of AWCA is conditional, influenced by concerns over durability, contamination risks, equipment performance and the persistent stigma associated with waste-based materials ([Jin et al., 2017](#)). Such perceptions align with global evidence that adoption decisions are shaped not only by material performance but also by socio-cultural meanings and client expectations ([Shooshtarian et al., 2020](#)). The absence of local demonstration projects limits observability, a key determinant of innovation adoption, underscoring the importance of real-world evidence and targeted communication. The barriers and drivers identified above can be mapped directly onto the theoretical constructs of the TPB and DoI, providing the analytical foundation for this study's structural models. Within the TPB, inadequate expertise (BR1, mean = 4.15) directly reduces PBC, the degree to which professionals believe they have the capacity to specify and supervise AWCA use. Insufficient testing standards (BR2, mean = 4.09) suppress trialability within the DoI framework by preventing professionals from evaluating AWCA performance on a small-scale or pilot basis. Resistance from the conventional aggregate industry (BR9) constitutes a compatibility barrier (DoI), as incumbent industry norms conflict with the integration of novel waste-derived materials into established procurement and specification workflows. Regarding drivers, partnership between waste processors and concrete producers (DV1, mean = 4.02) enhances compatibility (DoI) by embedding AWCA within familiar supply-chain relationships. Successful demonstration projects (DV3, mean = 3.97) are the primary mechanism for establishing observability (DoI), the degree to which innovation results are visible to potential adopters, simultaneously strengthening attitude (TPB) and perceived relative advantage. Government incentives and policy endorsement (DV9) constitute an institutional subjective norm (TPB), legitimising AWCA adoption in the professional community and reducing the social risk of specifying unfamiliar materials. From a practical perspective, this finding implies that increasing awareness alone will not lead to widespread adoption of AWCA. Instead, efforts must focus on improving professionals' perceptions through demonstration projects, clear performance standards and evidence of successful application. When professionals can observe the real-world performance of AWCA and trust its reliability, their willingness to adopt the material is likely to increase significantly.

Barrier analysis confirms that AWCA adoption is constrained primarily by structural and institutional deficiencies rather than individual resistance. Inadequate expertise, lack of standardised testing protocols, regulatory gaps and supply variability are consistent with international evidence on sustainable material barriers ([Tam et al., 2018](#); [Pacheco et al., 2023](#)). These findings highlight that adoption is not simply a matter of individual willingness but depends on the broader system within which professionals operate.

The SEM results further confirm that both knowledge and perception significantly influence adoption intention, with perception exerting a stronger effect, reinforcing evidence that intention emerges when awareness is combined with trust and reduced uncertainty ([Mujahid et al., 2024](#)). Notably, the R^2 values for the models are very similar (0.450 for knowledge and 0.448 for perception), indicating that both constructs explain nearly the same proportion of variance in intention. This similarity suggests that knowledge and perception are both important predictors of intention, but operate in different ways. This study posits that AWCA adoption requires a holistic strategy integrating capacity building, perceptual reframing, supply-chain development, regulatory support and circular economy principles ([Geissdoerfer et al., 2017](#)).

Conclusion and recommendations

Construction professionals recognise the sustainability potential of AWCA but lack confidence in its engineering applicability due to inadequate knowledge of material processing, mix design, testing procedures and performance standards. Evaluative beliefs regarding durability, client acceptance, contamination risks and long-term performance play a decisive role in shaping professionals' willingness to adopt AWCA. In addition, structural barriers, including the absence of national standards, insufficient testing protocols, weak supply chains and limited demonstration projects, continue to restrict market integration despite increasing environmental awareness. These findings underscore that AWCA adoption is not solely a technical issue but a broader socio-technical transition requiring coordinated institutional and industry-level action.

Aligning construction practices with circular economy principles, by valorising agricultural residues as construction inputs, offers significant potential to reduce environmental impacts, divert waste from landfills and improve resource efficiency. However, realising this potential requires deliberate collaboration among policymakers, industry actors and academic institutions. Addressing technical knowledge gaps through continuing professional development, strengthening perceptions through evidence-based demonstration projects, establishing national standards and certification frameworks, and stabilising supply chains through industry partnerships are critical steps towards wider adoption. Overall, this study provides empirical evidence to support policy development, industry transformation and future research on sustainable aggregates, positioning Ghana to advance circular construction practices in the developing world.

Implications for research

First, further research can utilise a longitudinal study to assess how construction professionals' knowledge, perceptions and intentions change when the drivers stated above are implemented. Another area for further research is combining experimental investigations with behavioural models by linking mechanical performance and life-cycle assessment of AWCA with professionals' perceptions to close the gap in technical validation and industry acceptance. Lastly, further research can examine different developing country contexts to examine waste availability, regulatory environments and how institutional maturity affects the perceptions of construction professionals.

Limitations

This study used a quantitative methodology only; however, subsequent studies can adopt a mixed-methods approach to authenticate the collected data by conducting interviews to confirm these findings. There is also a possibility of self-report bias due to the cross-sectional nature of the data. This study examined the behavioural dimension of AWCA rather than the engineering performance of AWCA. Another limitation is the use of purposive sampling to select the professionals. The findings reflect the views of a specific professional population and may not be generalisable to other construction professionals not considered in this study.

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