RESEARCH ARTICLE OPEN ACCESS

Spent Coffee Grounds and Wood Ash Mixture Partial Replacement for Sand and Cement Content in Concrete Interlocking Hollow Blocks: Mechanical Properties and Structural Integrity Investigation

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Abstract:
Concrete Hollow Blocks (CHB) are essential in construction for their structural integrity and cost-effectiveness, especially in building partitions. Traditional methods, however, demand high skill and lengthy processes, causing environmental damage through natural resource depletion and habitat destruction from CHB extraction and processing. This study aimed to develop Improved Concrete Hollow Blocks (ICHB) using spent coffee grounds and wood ash as partial replacements, evaluating their mechanical properties with Universal Testing Machines. The experimental research utilized Finite Element Analysis Software to analyze three sample types: mix 1 (control group) with a 1:4 concrete-to-sand ratio, mix 2 with 5% cement and sand replaced by wood ash and spent coffee grounds respectively, and mix 3 with 10% wood ash and 5% spent coffee grounds replacing cement and sand. Findings indicated that incorporating these materials in non-load-bearing ICHB could enhance sand and cement content. However, a 10% spent coffee grounds substitution could delay the hydration process due to its rapid moisture reaction. Efficient application of spent coffee grounds improved the compressive strength to 6.26 MPa, with a Poisson Ratio of 0.38 and a Modulus of Elasticity of 4137 MPa, making the material desirable for masonry wall construction. Further refinements could improve its suitability for various concrete applications. making it suitable for masonry wall construction. Further refinements could improve its application in concrete construction projects.

Keywords **—Construction, Finite Element Method, Interlocking Concrete Hollow Blocks Modulus of Elasticity, Poisson Ratio, Spent Coffee Grounds, Wood Ash**

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I. INTRODUCTION

Concrete hollow blocks (CHB) are vital in construction due to their strength, stability, and cost-efficiency, especially for high-rise buildings. However, traditional CHB construction is resource-intensive and environmentally harmful due to high cement usage, which depletes non-renewable resources and emits significant carbon dioxide.Researchers have explored using recycled materials like wood ash and spent coffee grounds (SCG) to partially replace cement and sand in CHB. Wood ash, a byproduct of burning wood, and SCG, waste from coffee brewing, can improve concrete properties and reduce environmental impact. This study developed interlocking concrete hollow blocks (ICHB) using these materials, suitable for temporary or emergency structures. Finite Element Analysis (FEA) tested three mixes, showing that wood ash and SCG could enhance compressive strength and other properties of non-load-bearing ICHB. The findings support the potential of these alternative materials for sustainable construction practices.

A. *Review of Related Literature and Studies*

Interlocking Blocks is a type of load-bearing block that interlocks to other hollow blocks. These blocks were placed on top of one another without the need of mortar [1]. They gained global recognition as an alternative to conventional blocks, because of their sustainability, lower production costs, and eco-friendliness, emitting fewer carbon emissions compared to standard blocks. [2]

A form of wood waste ash known as wood bottom ash (WBA) is created as a byproduct of the burning [3]. When regularly spread, wood ash wastes become a source of land pollution. Wood ash wastes affect soil pH influencing the surroundings [4]. Studies to include wood waste ash as a sustainable alternative on creating a cement mixture.

The surge in coffee consumption within the Philippines has inevitably translated into a corresponding increase in the generation of used coffee grounds [5]. Despite their biodegradable state, one primary factor that relatively negates spent coffee grounds' ability to decompose is low oxygen levels as they may take longer to decompose if they are crushed or buried in anaerobic (low oxygen) environments [6].

High compression strength was observed in the samples of 15% ratio containing wood ash replacement material [7]. However, with lower SCG ratios (0.6% to 3.0%), an unexpected spike in moisture absorption occurred at 6.0%; where smaller SCG particles led to a denser cementitious material, reducing water penetration and absorption in samples with lower SCG ratios. [8]

Poisson's ratio is a measurement of the lateral strain to linear strain ratio in the path of load. The range of Poisson's ratios is 0.15 to 0.25. Greater strength concrete exhibits brittleness when the value of Poisson's ratio is smaller. [9].

The modulus of elasticity is important in the design of flexural members as it shows the proportion of concrete that contributes to the flexural stiffness of the member. Elastic modulus is defined in relation to the tangent slope of the stress-strain curve at 25% of maximum stress [10]. The Modulus of Elasticity of a masonry material like Hollowed Concrete Block is averaging around 5898 MPa or 5.898 GPa. [11].

ANSYS FEM software was used to create a three-dimensional FEM for the purpose of analyzing pavements that had various block configurations and shapes [12]. Findings reveal that interlocking blocks induce lower stress and displacement along the x, y, and z axes compared to standard blocks. [13].

B. *Gap Analysis*

Previous studies on interlocking blocks have gaps in understanding their unique properties. Current research treats interlocking blocks like other concrete products, not requiring reinforcement steel bars. Questions remain about enhancing these blocks to resist water penetration, environmental conditions, and loads typical in engineering structures. To address this, software was used to measure material resistance and benefits for structural construction.Researchers focused on wood ash to improve hydration in interlocking blocks due to its calcium carbonate composition and pozzolanic properties. Wood ash enhances compressive strength but raises concerns about hydration capabilities. To mitigate moisture vulnerability from wood ash, spent coffee grounds (SCG) were used to replace part of the sand content, improving hydration and reducing water entrapment when used with wood ash, with an optimal ratio below 10%.Finite Element Analysis (FEA) was employed to gather data on the compression and tension properties of wood ash and SCG. However, key properties like Poisson's Ratio and Young's Modulus were not well-documented, which are essential for assessing structural integrity. The study aims to provide these data and compare the proposed materials with standard masonry units.

C. Statement of the Problem

Interlocking blocks, considered non-structural due to their non-load-bearing capacity, are increasingly popular worldwide for their ease of construction. However, conventional concrete materials pose environmental and structural challenges. Sand extraction leads to habitat loss and environmental degradation, while high demand depletes natural resources. Cement manufacturing is energy-intensive and contributes significantly to global CO_2 emissions. Researchers developed interlocking concrete blocks using spent coffee grounds and wood ash as partial substitutes to address these issues. They aimed to determine the ideal proportion of these materials, testing various replacement ratios (0:0, 5:10, 10:5, and 7.5:7.5). The study sought to evaluate the compressive strength and structural integrity of these blocks, assess the cost-effectiveness of production, and analyze their structural behavior using Finite Element Analysis, focusing on stress, deformation, and strain.

D. Objectives

To investigate the potential for sustainability improvements in construction, we aim to analyze the mechanical properties of interlocking blocks. These blocks will utilize a blend of spent coffee grounds and wood ash as substitutes for sand and cement, with analysis conducted through the Finite Element Method.Specific objectives include:

1. Evaluating the compressive strength properties of interlocking blocks incorporating spent coffee grounds and wood ash, comparing against conventional concrete blocks.
2. Using the Finite Element Method to assess the structural integrity of these interlocking blocks under lateral forces, focusing on stress, strain, and deformation, and their impact on overall concrete performance.
3. Conducting a cost-value analysis of these interlocking blocks, considering only material costs.
4. Identifying optimal ratios of wood ash and spent coffee grounds to replace sand and cement in the block mix design, aiming for a balance between improved structural performance and sustainability.

E. Scope and Limitations

The study aimed to assess the compressive properties, including Poisson's Ratio and Young's Modulus, of a new interlocking masonry unit and compare different formulations to gauge performance enhancement. Finite Element Analysis compared the material to conventional units under typical loads, suggesting potential structural benefits. Cost-value analysis evaluated the proposed system's cost-effectiveness against standard units. Limitations include partial replacement of cement and sand content and a focus on non-load-bearing design aspects. The study adhered to international design standards and considered interlocking standards where applicable. However, the cost-value analysis primarily focused on unit materials, overlooking other production-related expenses. While wood ash collection was acknowledged as a crucial component, specifics about its source were omitted due to variations in firewood sources.

II. METHODS

In civil engineering, Finite Element Analysis (FEA) using ANSYS is essential for refining structural designs and simulating real-world scenarios. Engineers utilize FEA to predict the responses of complex structures to various loads, such as wind, seismic activity, or traffic, by dividing large structures into smaller components for analysis. ANSYS provides a robust platform for structural analysis, enabling engineers to evaluate stress distribution, deformation, and stability, and to explore multiple design options to ensure the safety and durability of infrastructure projects.For this study, samples of spent coffee grounds and wood ash were used in different proportions as partial replacements for cement. The samples were divided into three mixes: Mix 1 (control) had no replacements, Mix 2 had 5% wood ash and 10% spent coffee grounds, and Mix 3 had 10% wood ash and 5% spent coffee grounds.

TABLE I
COMPOSITION PROPORTIONS OF INTERLOCKING BLOCKS

Mix	Cement (%)	Sand (%)	Wood Ash (%)	Spent Coffee Grounds (%)	Water Cement Ratio
1	20	80	0	0	0.6
2	15	70	5	10	0.6
3	10	75	10	5	0.6
4	12.5	72.5	7.5	7.5	0.6

The following table shows the composition proportions of the interlocking blocks and the sample quantities for compression tests. Cylindrical concrete samples were also created to determine Poisson's Ratio and Young's Modulus.

TABLE II
SAMPLES FOR COMPRESSION TEST

Days	Control	Spent Coffee Grounds And Wood Ash
7	1	1
14	1	1

Data acquisition involved documenting physical test results, including compressive strength tests, and gathering data from existing studies on sustainable construction practices. Materials and equipment used included cement, aggregates, wood ash, spent coffee grounds, molds, a compression testing machine, an oven, a sieve set, and a Universal Testing Machine. Laboratory testing adhered to standards such as ASTM and EN, ensuring proper evaluation of the concrete masonry units' properties.

Data analysis included conducting compressive tests on concrete samples with different mixture ratios to evaluate their mechanical properties. The most effective ratio identified was used to create interlocking blocks and additional concrete cylinder samples. The data collected were integrated into ANSYS to assess the material's structural integrity using the Finite Element Method/Analysis, determining its suitability for construction projects.Statistical analysis involved testing the compressive strength of concrete masonry products using a compliant compression testing machine, following standardized procedures. The compressive strength was calculated by using the formula below, with results reported in MPa or psi:

$$Compressive\ Strength = \frac{Maximum\ Load}{Cross - sectional\ Area\ of\ the\ Specimen.}$$

Guidelines from ASTM and EN ensured consistent evaluation, with specific requirements for non-load-bearing units to prevent misuse in load-bearing applications.

III. RESULTS AND DISCUSSION

F. Data Description

The study gathered data from two sources: experimental variables and a control standard provided by the Department of Public Works and Highway. Raw data collection employed tools and testing methods detailed earlier. Compressive strength tests for each mixture involved averaging the maximum load applied to samples per ratio, calculated based on net area. For Poisson Ratio and Modulus of Elasticity tests, two concrete cylinders were used to measure strain under force. Structural analysis utilized ANSYS, a Finite Element Analysis (FEA) software, to simulate the structural integrity of the interlocking blocks manufactured.

G. Data Analysis and Findings

1) Compressive Strength

The ICHB underwent the compressive strength test with the use of a universal testing machine to determine the maximum amount of compressive load that the block can endure. As per this study's objectives, the product samples underwent 7, 14, and 28 curing days, with three samples amounting to 12 ICHB samples tested for compressive strength test. In accordance with the DPWH Standard Specification for Item 1046—Masonry Work (1046.6 Strength Requirements) and the ASTM C129 Standard Specification for Non-Load Bearing Concrete Masonry Units, the compressive strength (average net area minimum) must be 500 psi (3.45 MPa) per individual unit or 600 psi (4.41 MPa) per average of 3 units.

TABLE III
COMPRESSIVE STRENGTH TEST RESULT FOR 7 DAYS CURING

SAMPLE	Length (mm)	Width (mm)	Maximum Force Applied (N)	Maximum Force Applied (N)	GrossArea Compressive Strength	
					MPa (N/mm^2)	psi (lb/in^2)
CONTROL (0:0)	380	100	38,000	125,220	3.30	477.94
WA-SCG	380	100	38,000	12,720	0.33	48.55

(10:5)						
SCG-WA (10:5)	380	100	38,000	4,000	0.11	15.27
WA/SCG (7.5:7.5)	380	100	38,000	13,020	0.34	49.69

The compressive strength test results revealed notable differences in strength between control concrete samples and those mixed with SCG-WA. Following the initial 7-day curing period, it became evident that Control Concrete ICHBs (Mixture 1) exhibited superior early strength compared to SCG-WA samples. The compressive strength of the Control Concrete reached 3.30 MegaPascals, making it 92.12% stronger than the average strength of the SCG-WA samples. Even when compared to the highest-performing SCG-WA sample, which had a replacement ratio of 7.5:7.5 (Mixture 4), the Control Concrete still outperformed, being 89.70% stronger. However, it's important to note that despite these improvements, none of the samples, including the Control Concrete, have yet met or surpassed the ASTM C129 compressive strength standards within the initial 7-day period.

TABLE IIV
COMPRESSIVE STRENGTH TEST RESULT FOR 14 DAYS CURING

SAMPLE	Length (mm)	Width (mm)	Maximum Force Applied (N)	Maximum Force Applied (N)	Gross Area Compressive Strength	
					MPa (N/mm^2)	psi (lb/in^2)
CONTROL (0:0)	382	97	37,054	115,990	3.13	454.01
WA-SCG (10:5)	377	100	37,700	12,150	0.32	46.74
SCG-WA (10:5)	380	99	37,620	56,500	1.50	217.83
WA/SCG (7.5:7.5)	379	100	37,900	17,410	0.46	66.63

Despite the ongoing progress in the compressive strength, concrete standards are yet to be met during the early stages of curing, suggesting further development is needed. However, by the 14th day of testing, there is notable improvement in strength. The Control Sample demonstrates the highest strength at 3.13 MPa, surpassing all replacement ratios. In comparison, the highest replacement ratio, Ratio 10:5, achieves a compressive strength of 1.50 MegaPascals, making the Control Sample 53.08% stronger. These findings highlight the significance of continued experimentation and refinement in optimizing concrete strength, particularly through the control of material ratios.

TABLE V
COMPRESSIVE STRENGTH TEST RESULT FOR 28 DAYS CURING

SAMPLE	Length (mm)	Width (mm)	Maximum Force Applied (N)	Maximum Force Applied (N)	Gross Area Compressive Strength	
					MPa (N/mm^2)	psi (lb/in^2)
CONTROL (0:0)	390	103	40,170	232,960	5.80	841.14
WA-SCG (10:5)	380	102	38,760	242,460	6.26	907.29
SCG-WA (10:5)	383	103	39,449	156,510	3.97	575.43
WA/SCG (7.5:7.5)	385	104	40,040	25,600	0.64	92.73

In the 28-day testing period, significant improvements in strength are evident across most samples, with their strengths often doubling compared to earlier testing phases. Notably, the SCG-WA Sample, with a replacement ratio of 5:10, exhibits the highest strength by the end of the curing period, despite initially displaying weaker compressive strength in earlier stages. This sample achieves a compressive strength of 6.26 MegaPascals, surpassing even the Control Concrete Sample, which also records a notable strength of 6.26 MegaPascals. Throughout the entire 28-day curing period, only two samples meet and exceed the ASTM C129 standard of 3.45 MegaPascals: the Control Sample (0:0 ratio) and the Wood Ash dominant sample (5:10 ratio), exceeding the standard by 40.52% and 44.89%, respectively. Additionally, the sample with the highest compressive strength at the 14th day, featuring a Sand-Cement Replacement Ratio of 10:5, records a strength of 3.97 MegaPascals at the 28th day, surpassing the ASTM C129 Standard by 13.10%. These findings highlight the effectiveness of various replacement ratios in enhancing the compressive strength of the concrete samples over the curing period.

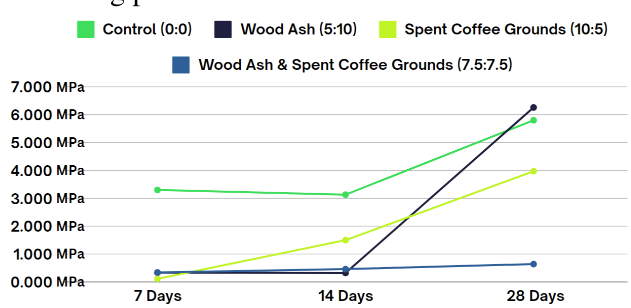

Fig. 3a Compressive Strength Chart of 4 Interlocking CHB Samples (in MPa)

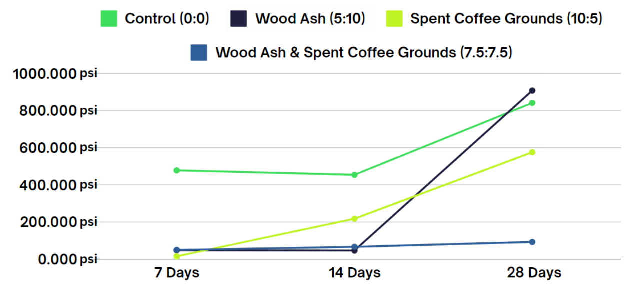

Fig. 3b Compressive Strength Chart of 4 Interlocking CHB Samples (in psi)

The charts show results of the Compressive Strength Test performed on interlocking concrete hollow blocks samples from 7 days to 28 days curing period. On the chart specified are the samples containing SCG-WA Replacement Ratios of 0:0, 5:10,10:5 and 7.5:7.5 respectively. The Ratio 7.5:7.5 of wood ash and spent coffee grounds sample dominant ICHB registered the lowest compressive strength 7 days to 28 days. On the other hand10:5 wood ash reached the highest possible compressive strength results 7 days up until 28 days the wood ash increased.

2) Poisson's Ratio

A series of experiments were conducted to determine the Poisson's Ratio and the Young's Modulus of Elasticity of the most optimal ratio of the researchers' specimen, Interlocking Concrete Hollow Blocks (Wood Ash - 10%, Spent Coffee Grounds – 5%). Three units were tested for the experiment, the samples were used for compressive testing, for Poisson's ratio and for Young's Modulus.

Wherein, the value of the Poisson's Ratio indicated from the testing is equivalent to 0.38. Where the value reached the range of the required Poisson's Ratio which is around 0.1 - 0.5.

3) Young's Modulus

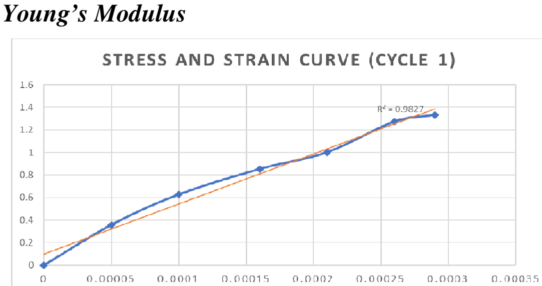

Fig. 4a. Stress and Strain Curve Cycle 1.

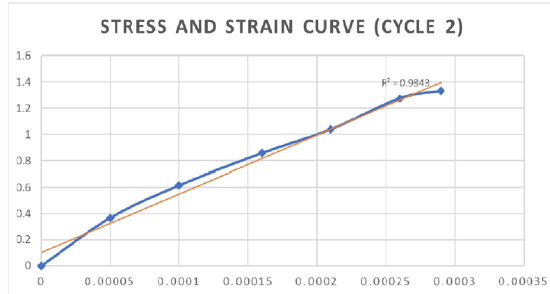

Fig. 4b Stress and Strain Curve Cycle 2

According to the test Results, the range of the Young's Modulus at cycle 1 *Figure 4(a)* and cycle 2 *Figure 4(b)* were 4,006 MPa and 4,084 MPa respectively, whereas the Stress-and-Strain Curves were almost linearly elastic. The Modulus of Elasticity average based on the data provided is at 4,137 MPa.

4) Finite Element Analysis: Stress

A longitudinal section in the vertical direction was utilized to analyze stress distribution within the prism. In the control sample, the highest lateral stress (Von Mises) measures 0.35853 MPa, with the lowest at 4.7942e-12 MPa. Conversely, the most optimal Interlocking Hollow Blocks sample, incorporating Spent Coffee Grounds and Wood Ash as partial replacements, records a highest lateral stress of 0.34646 MPa and a lowest of 3.9979e-12 MPa. The normal concrete sample exhibits a 3.37% higher stress level compared to the optimal sample. Critical stress areas are notably concentrated near column faces.

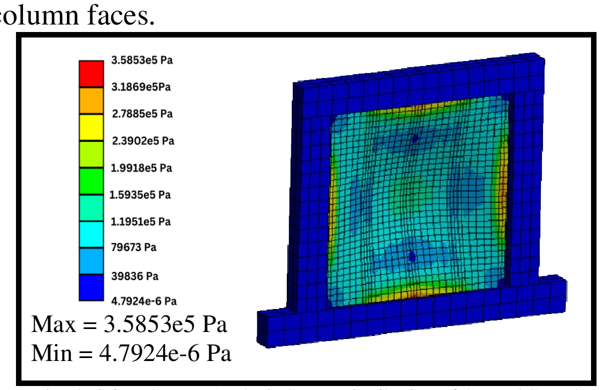

Fig. 5 Finite Element Analysis Stress Distribution of Control Sample

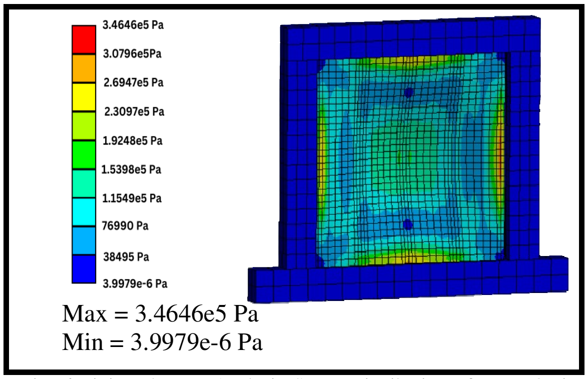

Fig. 6 Finite Element Analysis Stress Distribution of Most Optimal SCG-WA Sample

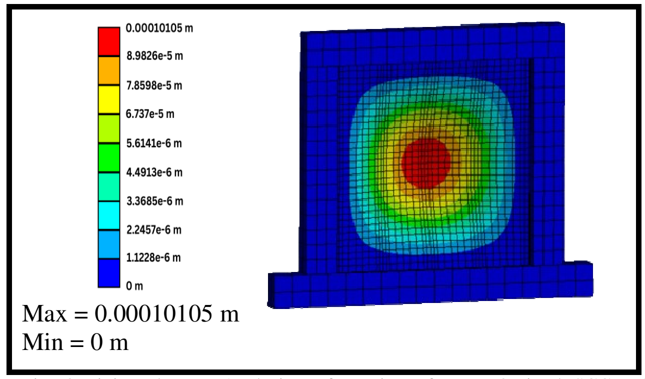

Fig. 8 Finite Element Analysis Deformation of Most Optimal SCG-WA Sample

The masonry wall prism braced by a frame when subjected to lateral force exhibits deformation due to stress applied. The most optimal sample of SCG-WA Interlocking Hollow Blocks exhibits greater deformation (0.00010105 m or 0.10105 mm) than the control sample (0.000015537 m or 0.015537 mm). The area near the frame experiences less deformation as it is braced by the two columns and beam. The area which shows the highest deformation for both prisms is found at its center because the Interlocking Hollow Blocks around that area are not that much supported by the beam and columns, thus, it is only supported by the grooves and its interlocking mechanism.

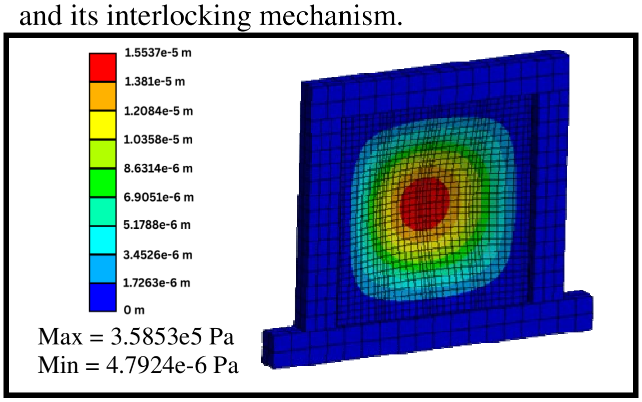

Fig. 7 Finite Element Analysis Deformation of Control Sample

When subjected to lateral force with bracing by a frame, a masonry wall prism displays deformation due to applied stress. The most optimal SCG-WA Interlocking Hollow Blocks sample exhibits greater deformation (0.10105 mm) compared to the control sample (0.015537 mm). Deformation is reduced near the frame due to support from columns and beams. However, the highest deformation occurs at the center of both prisms, where Interlocking Hollow Blocks lack support from columns and beams, relying solely on grooves and interlocking mechanisms for support.

5) *Finite Element Analysis:* Strain

During testing of a braced masonry wall prism subjected to lateral force, deformation occurred due to stress-induced strain, measured as the ratio of deformation to original size. The control sample displayed the highest and lowest elastic strains at 0.0000119510 and 2.203e-16 respectively, while the most optimal SCG-WA interlocking hollow block sample exhibited the highest and lowest elastic strains at 0.000083765 and 1.9361e-15 respectively. These results suggest that the most optimal SCG-WA interlocking hollow block sample experiences greater elastic strain compared to the control sample, attributed to its enhanced elastic deformation. Additionally, the optimal SCG-WA interlocking hollow block samples demonstrate higher Poisson Ratio and Young's Modulus, contributing to their increased elasticity

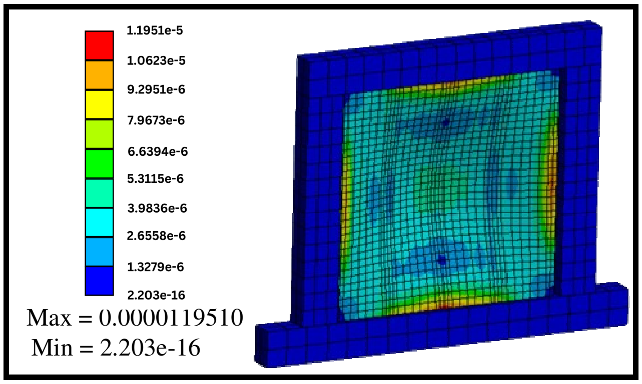

Fig. 9 Finite Element Analysis Elastic Strain of Control Sample

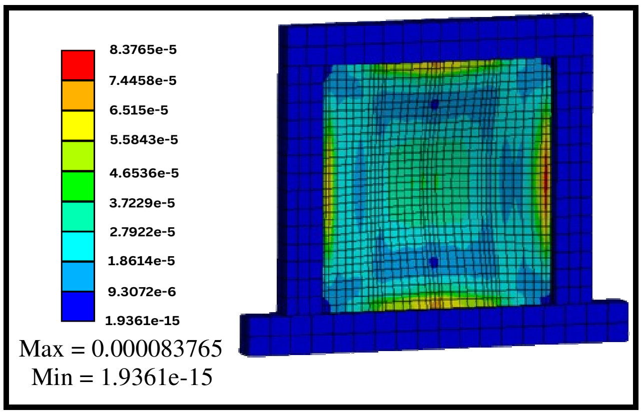

Fig. 10 Finite Element Analysis Elastic Strain of Most Optimal SCG-WA Sample

6) Cost Value Analysis

The production of Interlocking Concrete Hollow Blocks follows a ratio of 1:4, with one bag of Portland cement corresponding to four cubic feet of sand. The cost breakdown includes a price of 210 pesos per bag of ordinary Portland cement and 615 pesos per cubic meter of sand. Material preparation costs were omitted due to variations in electricity consumption for heavy-duty ovens and differing electricity rates. Researchers advocate for air drying or sun drying for spent coffee grounds (SCG) preparation, noting its scalability compared to oven drying. While air drying or sun drying methods incur no direct expenses, they necessitate significant time for material drying.

TABLE VI
DETAILED MATERIAL COST FOR THE PRODUCTION OF CONTROL ICHB

MATERIAL	QUANTITY	UNIT COST	TOTAL AMOUNT
Portland Cement	40kg/bag	₱ 210 / bag	₱ 210.00
Sand	4 cu.ft	₱ 8000 / 460	₱ 70.00
		cu.ft	
TOTAL			₱ 280.00

The ICHB produced measures 380 mm x 100 mm x 180 mm, the material cost of ₱ 280 can produce up to 30 blocks of ICHB. The ICHB will cost ₱ 9.33 or ₱ 10 per unit considering the material cost alone.

Wood Ash and Spent Coffee Grounds materials were gathered as residue from Chicharon production in Betis, Guagua Pampanga and several Starbucks Coffee Chain around San Fernando, Pampanga. The researchers gathered this material for free as these materials will just be thrown away. The same ratio was followed in producing the ICHB, but considering the replacement of sand and cement with spent coffee grounds and wood ash respectively, the amount of sand and cement is reduced in production of ICHB. Considering the most optimal sample of SCG-WA Interlocking Hollow Blocks with replacement of 10% for cement and 5% for sand the amount of material and cost are as shown:

TABLE VII
AMOUNT AND COST FOR CEMENT USED IN FOR PRODUCING OF 10:5 WA-SCG ICHB

UNIT DESCRIPTION	AMOUNT
Portland Cement	**₱ 210.00 per 40 kg bag**
10% of 40 kg	40kg x 0.10 = **4 kg**
Total for Ordinary Portland Cement Considering a 10% Replacement of Wood Ash to Cement Content	40 kg - 4 kg = **36 kg**
TOTAL COST: By interpolation, the cost of 36 kg of Ordinary Portland Cement is equal to **₱189.00.**	

TABLE VIII
AMOUNT AND COST FOR CEMENT USED IN FOR PRODUCING OF 10:5 WA-SCG ICHB

UNIT DESCRIPTION	AMOUNT
Sand	**₱ 70 per 4 cu.ft**
5% of 4 cubic feet	4 cu. ft x 0.05 = **0.2 cu.ft**
Total for Sand Considering a 5% Replacement of with Wood Ash	4 ft3 - 0.2ft3 =**3.8 cu.ft**
TOTAL COST: By interpolation, the cost of 3.8 ft3 of Sand is equal to **₱66.50.**	

TABLE IX
DETAILED MATERIAL COST FOR THE PRODUCTION OF WA-SCG REPLACED ICHB

MATERIAL	QUANTITY	UNIT COST	TOTAL AMOUNT
Portland Cement	40kg/bag	₱ 210 / bag	₱ 210.00
Sand	4 cu.ft	₱ 8000 / 460 cu.ft	₱ 70.00
TOTAL			₱ 280.00

The ICHB with materials partially replaced by SCG and WA measures 380 mm x 100 mm x 180 mm, the material cost of ₱ 255.5 can produce up to 30 blocks of ICHB, the same as the control sample. The most optimal ICHB with materials partially replaced by SCG and WA will cost ₱ 8.51 or ₱ 9 per unit considering the material cost alone.

The ICHB with partially replaced materials of cement and sand with wood ash and spent coffee grounds respectively is visibly much cheaper than the ICHB control sample made from cement and sand. The most optimal mixture of SCG-WA Interlocking Hollow Blocks has a compressive strength of 6.26 MPa or 907.29 psi compared to the control sample compressive strength of 5.80 MPa or 841.14 psi. The most optimal mixture of SCG-WA Interlocking Hollow Blocks offers greater strength while being cheaper than the control sample. Wood Ash and Spent Coffee Grounds replacement for Sand and Cement in production of Interlocking Concrete Hollow Blocks is more economical on material aspect alone, at the same time offers the quality greater than the control or conventional mixture of sand and cement in production of ICHB.

IV. CONCLUSIONS AND RECOMMENDATIONS

The study concludes that incorporating spent coffee grounds (SCG) and wood ash (WA) into non-load bearing interlocking hollow blocks (ICHB) offers significant benefits, though certain factors need consideration. A higher SCG replacement content of 10% can slow hydration due to SCG's immediate reaction to moisture, while an equal replacement of 7.5% SCG and WA is ineffective because SCG's reactivity may hinder WA's strength-enhancing capabilities. Despite this, WA improves compressive properties compared to control samples. The optimal replacement ratio identified is 5% SCG with sand and 10% WA with cement, resulting in economical ICHBs with enhanced structural integrity, increased Poisson's ratio, and Young's Modulus, indicating improved elasticity for masonry applications. The study recommends further improvements such as establishing efficient interlocking molds to expedite production, introducing machinery to enhance interlocking accuracy, and testing different replacement ratios for better mechanical properties. Additionally, it suggests exploring alternative curing methods, investigating other mechanical properties like fire resistance and water absorption, and studying the effects of SCG age on concrete performance, as storage duration may impact compressive strength and other properties.

REFERENCES

[1] J. Li, H. Zhou, W. Chen, and Z. Chen, "Mechanical Properties of a New Type Recycled Aggregate Concrete Interlocking Hollow Block Masonry," Sustainability, vol. 13, no. 2, pp. 745–745, Jan. 2021, doi: https://doi.org/10.3390/su13020745.

[2] A. Aswad, Murat Yılmaz, and Salah Haj İsmail, "A systematic review study on different kinds of interlocking concrete blocks designs and properties," Turkish Journal of Engineering, vol. 6, no. 4, pp. 327–337, Oct. 2022, doi: https://doi.org/10.31127/tuje.931076.

[3] Akinyemi Banjo Ayobami, "Performance of wood bottom ash in cement-based applications and comparison with other selected ashes: Overview," Resources, Conservation and Recycling, vol. 166, pp. 105351–105351, Mar. 2021, doi: https://doi.org/10.1016/j.resconrec.2020.105351.

[4] R. Martínez-García et al., "The Present State of the Use of Waste Wood Ash as an Eco-Efficient Construction Material: A Review," Materials, vol. 15, no. 15. MDPI AG, p. 5349, Aug. 03, 2022. doi: 10.3390/ma15155349. Available: http://dx.doi.org/10.3390/ma15155349

[5] Systematic Mapping on Adsorption Studies Using Spent Coffee Grounds Therese Jan E. Mangussad, Frence Laurice Ghayle A. Nuñez, Jean E. Topacio Research Congress 2021: Contemporary Trends in Science and Education https://animorepository.dlsu.edu.ph/conf_shsrescon/2021/paper_see/7/](https://animorepository.d

[6] M. Kitou and S. Okuno, "Decomposition of coffee residue in soil," Soil Science and Plant Nutrition, vol. 45, no. 4. Informa UK Limited, pp. 981–985, Dec. 1999. doi:10.1080/00380768.1999.10414348.Available: http://dx.doi.org/10.1080/00380768.1999.10414348

[7] Subramaniam, P.; Subasinghe, K.; Fonseka, W.R.K. Wood Ash as An Effective Raw Material for Concrete Blocks. Int. J. Res. Eng. Technol. 2015, 4, 228–233

[8] R. Roychand et al., "Transforming spent coffee grounds into a valuable resource for the enhancement of concrete strength," Journal of Cleaner

Production, vol. 419, p. 138205, 2023. doi:https://doi.org/10.1016/j.jclepro.2023.138205

[9] R. Roychand, S. Kilmartin-Lynch, M. Saberian, J. Li, G. Zhang, and C. Q. Li, "Transforming spent coffee grounds into a valuable resource for the enhancement of concrete strength," Journal of Cleaner Production, vol. 419. Elsevier BV, p. 138205, Sep. 2023. doi: 10.1016/j.jclepro.2023.138205. Available: http://dx.doi.org/10.1016/j.jclepro.2023.138205

[10] B. V. Mane and A. N. Patil, "An experimental study of the relationship between modulus of elasticity, Poisson's ratio, and the mechanical properties of high-performance concrete," Discover Civil Engineering, vol. 1, no. 1, Apr. 2024. doi:10.1007/s44290-024-00003-z

[11] A. G. Krishna, "STRENGTH STUDY ON REINFORCED HOLLOW CONCRETE BLOCK MASONRY," International Journal of Applied Engineering Research, vol. 13, no. 0973–4562, pp. 270–273, 2018. doi:https://www.ripublication.com/ijaerspl2018/ijaerv13n7spl_56.pdf

[12] D. Gunatilake and W. K. Mampearachchi, "Finite element modelling approach to determine optimum dimensions for interlocking concrete blocks used for road paving," Road Materials and Pavement Design, vol. 20, no. 2. Informa UK Limited, pp. 280–296, Oct. 11, 2017. doi: 10.1080/14680629.2017.1385512. Available: http://dx.doi.org/10.1080/14680629.2017.1385512

[13] Kumar, R., & Hussain, S. (2021). Seismic analysis of interlocking blocks of wall. International Journal of Advances in Engineering and Management, 3(7), 3369–3385. https://doi.org/10.35629/5252-030733693385

