



## Utilization of Oyster Shells as a Substitute Part of Cement and Fine Aggregate in the Compressive Strength of Concrete

Bunyamin Bunyamin<sup>1\*</sup>, Amir Mukhlis<sup>1</sup>

<sup>1</sup>Department of Civil Engineering, Faculty of Engineering, Universitas Iskandar Muda, Banda Aceh, Indonesia;

\*Corresponding author email: [bunyamin@unida-aceh.ac.id](mailto:bunyamin@unida-aceh.ac.id)

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**Abstract** – The compressive strength of concrete depends on the physical characteristics of the concrete forming materials. Oyster shells originating from Krueng Neng, Aceh Besar are very abundant, left unattended by fishermen, causing pollution of the surrounding environment. Oyster shell dust contains CaO, which can be used as a partial substitution of cement. Therefore, it is necessary to study oyster shell ash as cement replacement and fine aggregate in concrete production. This research aims to determine the compressive strength of concrete using shell ash as cement replacement and fine aggregate. The oyster shells were obtained from Krueng Neng, Lamjamee Village, Jaya Baru, Aceh Besar District. The oyster shells were crushed with a Los Angeles Test machine and sieved with sieve size 2.36 mm for fine aggregate and sieve #200 for cement replacement. The water-cement ratios (w/c) were 0.4, 0.5 and 0.6. The results showed that concrete's compressive strength with 5% cement replacement level was higher than the concrete with cement only. Meanwhile, for other replacement levels, the compressive strengths of concrete specimens were lower than control specimens.

**Keywords:** Oyster Shell, Waste, Ash, Compressive Strength, Concrete.

### Introduction

Various research and methods are currently carried out and are continuously being developed to increase concrete strength, one of which is the concrete-forming materials. This is done by substituting alternative materials, coarse aggregate, fine aggregate, cement, and additives to increase the binder's adhesion in the concrete. The materials used as substitutes are focused on utilizing waste materials. The use of waste materials that have the potential to contain CaO as a substitute for part of the cement in the concrete will affect the strength of the concrete, resistance to hot or cold temperatures, corrosion resistance, and setting time (initial time and end time for binding the paste) (De Belie et al., 2018).

Oyster shell is a waste material that can pollute the environment and is used as a substitute for coarse aggregate by 50%, indicating that the weight of concrete in 1 m<sup>3</sup> is 1993 kg/m<sup>3</sup> and classified as lightweight concrete. The water absorption capacity for hollow concrete, which was replaced by a 50% oyster shell of fine aggregate, is still within the allowable limits (Eo & Yi, 2015).

Oyster shell ash can be applied as a substitute for cement in a masonry and plastering mortar mixture and can improve its workability (Lertwattanaruk, Makul, & Siripattaraprat, 2012). Oyster shells' potential as a substitute for cement is very large because 100 grams of oyster shells contain 52 grams of CaO and 48 grams of other chemical substances (Ayyappan, 2018). The use of oyster shell grain as a concrete mixture has been widely used. This is due to high CaO content. Oyster shell ash contains pozzolanic chemical compounds, which contain lime (CaO), alumina, and silica compounds. It can be used as an alternative concrete raw material (Li, Song, & Hong, 2007). Oyster shell waste can be used as a substitute part of the concrete's cement because it is similar to

a lime. However, mixing oyster shell waste with cement up to 25% will reduce the concrete quality (Ubachukwu & Okafor, 2019).

Several studies have been carried out and resulted in different oyster shell density. Oyster shell-specific gravity was obtained at 3.09 (Binag, 2016), 2.65 (Lertwattanakul et al., 2012), and 2.33 (Adewuyi, Franklin, & Ibrahim, 2015). The addition of 10%, 15%, and 20% oyster shell grain to cement can increase concrete strength (Ayyappan, 2018).

In ancient China and Taiwan for hundreds of years ago, oyster ash was used as a substitute for cement in building temples. Research on oyster ash as a substitute for cement shows a significant ratio between tensile strength and compressive strength compared to conventional concrete. The results showed that the splitting tensile strength of concrete using oyster shell ash as cement replacement was 16.1% - 19.9% of the compressive strength. Simultaneously, the conventional concrete shows a tensile splitting strength of 10% - 14% of the compressive strength (Chang et al., 2019).

Seashell ash, which is used as a substitute for part of the cement by 15%, can improve the concrete's quality. Concrete with seashell ash as a substitute for part of the cement produces high-quality concrete, namely chemical composition, specific gravity, compressive strength, flexural strength, and tensile strength. Seashells are waste from the sea that can be used optimally to solve environmental pollution problems by using them as a substitute for cement in concrete (Mohammad et al., 2017).

The protein content in oysters is a type of food that comes from the sea, which is quite abundant; of course, the number of shells will also be comparable. So far, oyster shells that are no longer used by fishermen are thrown away and left alone, causing environmental pollution. In this study, therefore, oyster shells from Krueng Neng, Aceh Besar were used as an added material in the manufacture of concrete. The combination of grain and ash from Krueng Neng's oyster shell was incorporated into the concrete-forming material. This research hopes that Krueng Neng's oyster shells can be used as a partial cement replacement and fine aggregate and can reduce environmental pollution.

The objectives of this study are as follows: to utilize waste from Krueng Neng, Aceh Besar, namely oyster shells to be a partial cement replacement material and fine aggregates, to determine the hardened concrete density and compressive strength of concrete with the addition of ash and grain of Krueng Neng's oyster shells.

## **Materials and Method**

### **Materials**

The materials used in this research are cement, oyster shell grain, oyster shell ash, fine sand, coarse sand, coarse aggregate, and water. The cement used is Portland cement from PT Semen Andalas with a specific gravity of 3.15. Fine and coarse aggregates were originated from Jantho, Aceh Besar. Meanwhile, oyster shell waste was collected from Krueng Neng, Aceh Besar. The oyster shell was used as partial replacements for cement and fine aggregate.

The type of oyster shell used in this study was *Crassostrea Gigas* (Octavina, Yulianda, & Krisanti, 2014). The oyster shells were burned at a temperature of 200 °C in a drum. The burned oyster shells were then crushed by using a *Los Angeles Test* machine in the laboratory. The resulting grain was crushed again manually by using a crusher. The oyster shell ash was sieved by 2.36 mm sieve size for fine aggregate replacement and #200 sieve size for cement replacement. The chemical composition and physical properties of oyster shells are presented in Tables 1 and 2. The physical properties of aggregate were also examined using American Society for Testing and Materials (ASTM) Standards, and the results are presented in Table 2. It is, however, important to say that these physical properties fulfilled the ASTM requirements.

Table 1. Chemical composition of oyster shell ash.

No.	Chemical composition	Total (%)
1	SiO <sub>2</sub>	1.60
2	Al <sub>2</sub> O <sub>3</sub>	0.92
3	CaO	51.56
4	MgO	1.43
5	Na <sub>2</sub> O	0.08
6	K <sub>2</sub> O	0.06
7	H <sub>2</sub> O	0.31
8	LOI	41.84

Table 2. Physical properties of aggregate and oyster shell ash.

No.	Properties	Fine Sand	Coarse Sand	Coarse Aggregate	Oyster Shell
1	Bulk density (kg/l)	1.709	1.760	1.848	1.152
2	Fineness modulus	2.760	3.200	6.910	2.000
3	Specific gravity (SSD)	2.706	2.737	2.717	2.330
4	Specific gravity (OD)	2.610	2.663	2.622	-
5	Water absorption (%)	3.678	2.786	3.634	2.900

### Mix proportion and preparation of specimens

The mix proportion of concrete was designed based on American Concrete Institute (ACI) 2005, and three different water-cement ratios ( $w/c = 0.4, 0.5, \text{ and } 0.6$ ) were used (ACI, 2005). The cement and fine aggregate weight for each ratio were replaced by oyster shell ash and grain, respectively, at the replacement levels of 0%, 5%, 10%, and 15%. Therefore, 12 mixtures, as shown in Table 3, were obtained. The slump of fresh concrete was designed at 75-100 mm with a maximum aggregate diameter of 25.4 mm. The maximum size of fine sand and coarse sand was 4.76 mm and 9.52 mm, respectively (Bunyamin, 2019). The mix proportion for all mixtures is shown in Table 3.

The specimens used in this study were cylinders with a diameter of 150 mm and a height of 300 mm. Five specimens were prepared for each mixture. The specimens were produced by mixing all the materials in Table 3 in a concrete mixer and stirred for approximately 10 minutes. The homogenous mixture was then cast in cylinder molds in three layers, with each of the layers was compacted by a steel bar with round tips and tapped using a rubber hammer. The molds were removed after the specimens' age was 24 hours, and the specimens were then cured by soaking them in fresh water for 28 days.

Table 3. Mix proportion of concrete.

Name of Specimen	W/C	C-OSA %	C-OSG %	W Kg/m <sup>3</sup>	C Kg/m <sup>3</sup>	OSA Kg/m <sup>3</sup>	CA Kg/m <sup>3</sup>	CS Kg/m <sup>3</sup>	FS Kg/m <sup>3</sup>	OSG Kg/m <sup>3</sup>
NC-0.40	0.4	0	0	187	467	0	1274	254	214	0
OS5-0.40		5	5	187	444	23	1274	254	203	11
OS10-0.40		10	10	187	420	47	1274	254	192	21
OS15-0.40		15	15	187	397	70	1274	254	182	32
NC-0.50	0.5	0	0	187	373	0	1274	304	256	0
OS5-0.50		5	5	187	355	19	1274	304	244	13
OS10-0.50		10	10	187	336	37	1274	304	231	26
OS15-0.50		15	15	187	317	56	1274	304	218	38
NC-0.60	0.6	0	0	187	311	0	1274	338	285	0
OS5-0.60		5	5	187	296	16	1274	338	271	14
OS10-0.60		10	10	187	280	3	1274	338	256	28
OS15-0.60		15	15	187	265	47	1274	338	242	43

where: W/C = water cement ratio; C-OSA = content of oyster shell ash as cement replacement; C-OSG = content of oyster shell grain as fine aggregates replacement; W = water; C = cement; OSA = oyster shell ash; CA = coarse aggregate; CS = coarse sand; FS = fine sand; and OSG = oyster shell grain.

### Compressive strength test

The compressive strength of concrete was tested according to ASTM C39/C39M-20 at the age of specimens of 28 days (ASTMC39/C39M-20, 2012). The specimens were removed from the water and dried. Before the compression test was conducted, the weight of the specimens was measured, and the hardened concrete density can be calculated as follows:

$$D = \frac{W}{V} \quad (1)$$

where: D = hardened concrete density (kg/m<sup>3</sup>); W = weight of concrete specimen (kg); and V = volume of concrete specimen (m<sup>3</sup>).

A compression test was conducted on the specimens using a universal testing machine. The cylinder specimen was placed between two loading plates, and the load was applied until the sample was destroyed. The compressive strength of concrete was then calculated as follows:

$$f'c = \frac{P}{A} \quad (2)$$

where: f<sub>c</sub> = compressive strength of concrete (MPa); P = maximum compressive load (N); and A = cross-sectional area of the specimen (mm<sup>2</sup>).

## Results

### Compressive strength

The average compressive strength of all concrete mixture at 28 days old is shown in Figure 1. Figure 1 shows that the compressive strength of concrete with w/c of 0.40 without using oyster shell grain was 31 MPa, while the value for mixture with 5% oyster shell grain increased to 32 MPa. Meanwhile, the mixture's compressive strength with 10% and 15% oyster shell grain decreased again to 31 MPa and 27 MPa, respectively. Compressive strength of concrete with w/c of 0.50 without using oyster shell grain was 28 MPa, while the value for mixture with 5% and 10% oyster shell grain increased to 33 MPa and 29 MPa, respectively. Meanwhile, the mixture's compressive strength with 15% oyster shell grain decreased again to 25 MPa. Compressive strength of concrete with w/c of 0.60 without using oyster shell grain was 24 MPa, while the value for mixture with 5% and 10% oyster shell grain increased to 23.89 MPa and 24.15 MPa, respectively. Meanwhile, the mixture's compressive strength with 15% oyster shell grain decreased again to 19 MPa.

### Concrete density

The average of hardened concrete density for all mixtures tested in this study is shown in Figure 2. Figure 2 shows that the density of concrete with w/c of 0.40 without using oyster shell grain was 2472 kg/m<sup>3</sup> while the value for mixture with 5%, 10%, and 15% oyster shell grain decreased to 2427 kg/m<sup>3</sup>, 2419 kg/m<sup>3</sup>, and 2422 kg/m<sup>3</sup>, respectively. The density of concrete with w/c of 0.50 without using oyster shell grain was 2461 kg/m<sup>3</sup>, while the value for mixture with 5% oyster shell grain increased to 2464 kg/m<sup>3</sup>. Meanwhile, the mixture's concrete density with 10% and 15% oyster shell grain decreased to 2437 kg/m<sup>3</sup> and 2424 kg/m<sup>3</sup>, respectively. The density of concrete with w/c of 0.60 without using oyster shell grain was 2451 kg/m<sup>3</sup> while the value for mixture with 5%, 10%, and 15% oyster shell grain decreased to 2445 kg/m<sup>3</sup>, 2434 kg/m<sup>3</sup>, and 2420 kg/m<sup>3</sup>, respectively.

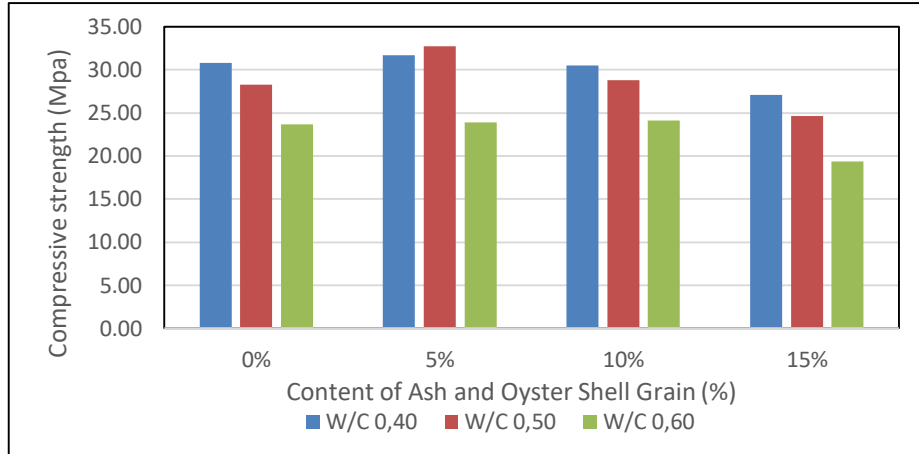


Fig. 1 Compressive strength of concrete.

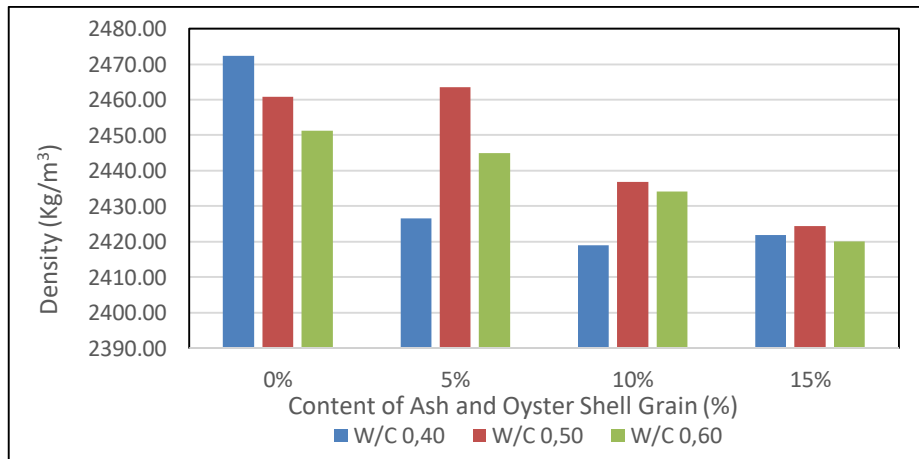


Fig. 2 Density of concrete.

## Discussion

As shown in Figure 1, the utilization of oyster shell ash and grain as cement and fine aggregate replacement at the content of 5% increased the compressive strength of concrete with w/c of 0.40 and 0.50. Furthermore, for concrete mixtures with a w/c of 0.60, the compressive strength of concrete with 5% and 10% replacement levels was higher than that of control specimens. The higher compressive strength with oyster shell ash and grain was due to the high content of CaO in oyster shell ash. This CaO during hydration of cement produces the so-called calcium silicate hydrate, which is the main contributor to the concrete compressive strength. Increasing the replacement level by more than 10% causes some oyster shell ash to not react during the hydration process, resulting in lower compressive strength. The relationship between the compressive strength of concrete and oyster shell ash and grain content is shown in Figure 3. Figure 1 also shows that the compressive strength of concrete increased with the decreasing of w/c, and these results are in line with the reports of several researchers [(Saidi & Hasan, 2020); (Singh, Munjal, & Thammishetti, 2015); (Nahhab & Zahra, 2018)].

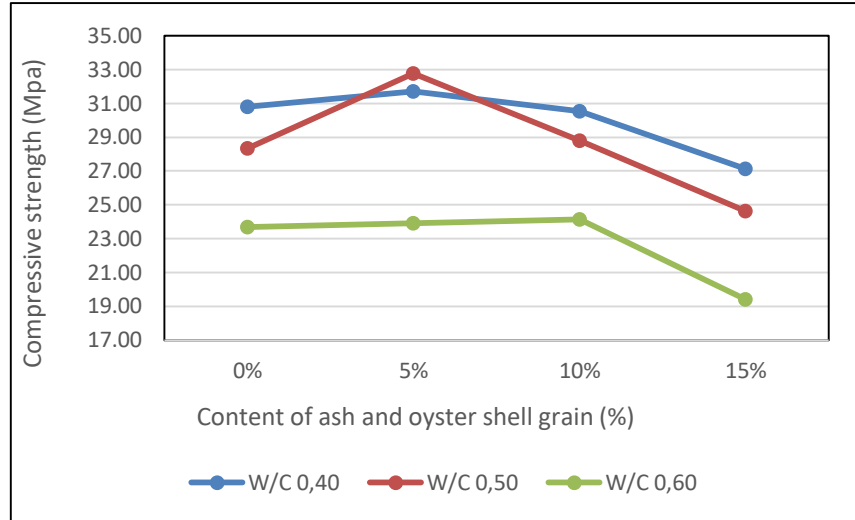


Fig. 3 Relationship between concrete compressive strength and oyster shell ash and grain content.

Figure 2 shows that the density of concrete containing oyster shell ash and grain was lower than that of control specimens. The lower density of concrete causes the reduction of dead load carries by structures resulting in safer structures. However, as shown in Figure 4, the reduction of concrete density due to oyster shell ash and grain utilization was not significant. All the mixture had a density in the range of normal-weight concrete.

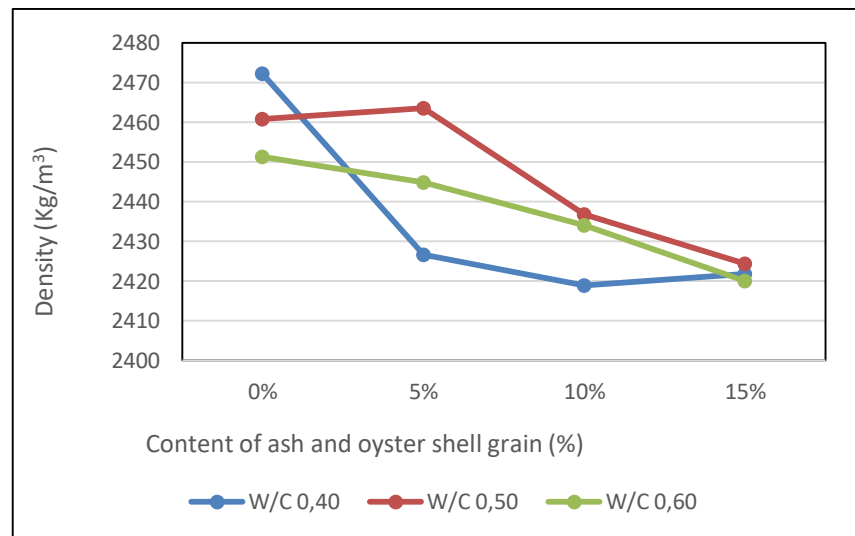


Fig. 4 Relationship between concrete density and oyster shell ash and grain content.

### Conclusion

From this study, several conclusions can be drawn: replacement of cement and fine aggregate with ash and oyster shell grain at 5%, 10%, and 15% content affect the concrete compressive strength. The highest concrete compressive strength for the mixture with water-cement ratios of 0.40 and 0.50 are obtained at a 5% replacement level of cement. The highest concrete compressive strength for mixture with water-cement ratios of 0.60 is obtained at a 10% replacement level of cement. The density of hardened concrete decreases with increasing oyster shell ash and grain content—the compressive strength of concrete containing oyster shell ash and grain increases with decreasing of the water-cement ratio.

The recommendation for continuing this research is the burning temperature of oyster shell ash. To obtain similar physical properties with cement, it is better to try with a temperature greater than 700° C. Hence, oyster shell ash's physical properties can improve the compressive strength at a 15% replacement level of cement.

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### **References**

- ACI, A. C. I. 2005. *Manual of concrete practice*. Parts.
- Adewuyi, A. P., Franklin, S. O., & Ibrahim, K. A. (2015). Utilization of mollusc shells for concrete production for sustainable environment. *International Journal of Scientific & Engineering Research*, 6(9).
- ASTMC39/C39M-20. 2012. *Standard test method for compressive strength of cylindrical concrete specimens*.
- Ayyappan, K. (2018). Study on Structural Behavior of Oyster Shell Powder in Concrete. *Journal of Engineering and Applied Sciences*.
- Binag, N. D. 2016. Powdered shell wastes as partial substitute for masonry cement mortar in binder, tiles and bricks production. *Int. J. Eng. Res. Technol*, 5, 70–77.
- Bunyamin. 2019. Comparison of deflection of hollow block concrete blocks with normal reinforced concrete beam. *AIP Conference Proceedings*, 2059(1), 20039.
- Chang, C.-J., Chang, T.-P., Chen, C.-T., & Liu, Y.-W. 2019. Mix Proportion and Engineering Behavior of San-Ho-Tu Building Material for Temples and Ancestral Clan Houses. In *Structural Analysis of Historical Constructions* (pp. 1585–1593). Springer.
- De Belie, N., Soutsos, M., & Gruyaert, E. 2018. *Properties of Fresh and Hardened Concrete Containing Supplementary Cementitious Materials*. Springer.
- Eo, S.-H., & Yi, S.-T. 2015. Effect of oyster shell as an aggregate replacement on the characteristics of concrete. *Magazine of Concrete Research*, 67(15), 833–842.
- Lertwattanaruk, P., Makul, N., & Siripattarapratvat, C. 2012. Utilization of ground waste seashells in cement mortars for masonry and plastering. *Journal of Environmental Management*, 111, 133–141. <https://doi.org/10.1016/J.JENVMAN.2012.06.032>
- Li, Y., Song, W. D., & Hong, P. Z. 2007. Changing wastes into valuables-discussion on comprehensive development and utilization of oyster shell. *Doctor. Expert Forum*, 26.
- Mohammad, W. A. S. B. W., Othman, N. H., Ibrahim, M. H. W., Rahim, M. A., Shahidan, S., & Rahman, R. A. 2017. A review on seashells ash as partial cement replacement. *IOP Conference Series: Materials Science and Engineering*, 271(1), 12059.
- Nahhab, A. H., & Zahra, G. F. A. 2018. volumechange and strength characteristics of normal and high-strength mortars: effect of aggregate type and water-binder ratio. *Cogent Engineering*, 5(1), 1542928.
- Octavina, C., Yulianda, F., & Krisanti, M. 2014. Struktur komunitas tiram dagingdi perairan estuaria Kuala Gigieng, Kabupaten Aceh Besar, Provinsi Aceh. *DEPIK Jurnal Ilmu-Ilmu Perairan, Pesisir Dan Perikanan*, 3(2).
- Saidi, T., & Hasan, M. 2020. The effect of partial replacement of cement with diatomaceous earth (DE) on the compressive strength, absorption of mortar. *Journal of King Saud University-Engineering Sciences*.
- Singh, S. B., Munjal, P., & Thammishetti, N. 2015. Role of water/cement ratio on strength development of cement mortar. *Journal of Building Engineering*, 4, 94–100.
- Ubachukwu, O. A., & Okafor, F. O. 2019. Investigation of the Supplementary Cementitious Potentials of Oyster Shell Powder for Eco-Friendly and Low-cost Concrete. *Electronic Journal of Geotechnical Engineering*, 24(5), 1297–1306.