

Effect of sugarcane leaf ash on the compressive strength and shear bond strength of API class G well cement

Jayadi Wahid¹, Deny Fatryanto Edyzoh Eko Widodo¹, Aprilino Alfa Kurmasela¹

¹ Sekolah Tinggi Teknologi Minyak dan Gas Bumi Balikpapan

Correspondence: jayaadi28@gmail.com

Article Info

Article history:

Received Jun 12th, 2026

Revised Aug 26th, 2026

Accepted Aug 29th, 2026

Keywords:

Sugarcane leaf ash; API Class G; compressive strength; well cement; shear bond strength.

ABSTRACT

Well cementing is an important stage in oil and gas drilling operations that aims to maintain well integrity by forming a strong bond between the casing and formation. One effort to improve the quality of well cement is to utilize pozzolanic materials from agricultural waste, such as sugarcane leaf ash. This study aims to analyze the effect of adding sugarcane leaf ash on the compressive strength and shear bond strength of API Class G well cement. The study used a laboratory experimental method with sugarcane leaf ash concentration variations of 0%, 1%, 2%, 3%, and 4% by weight of cement (BWOC). Specimens were prepared through mixing, molding, and curing processes, followed by testing using a hydraulic press. The test data were analyzed descriptively to evaluate changes in mechanical properties at each additive concentration. The results showed that adding sugarcane leaf ash affected the compressive strength and shear bond strength of API Class G well cement. The highest compressive strength of 629.86 psi was obtained at a concentration of 2% BWOC, while the highest shear bond strength of 1,102.13 psi was obtained at concentrations of 1% BWOC and 2% BWOC. Adding sugarcane leaf ash above the optimum concentration caused a decrease in the mechanical properties of the cement, indicating that increasing the additive concentration does not always result in increased strength. The results indicate that sugarcane leaf ash has potential as an alternative additive for API Class G well cement, with an optimum concentration of 2% BWOC based on the compressive strength and shear bond strength parameters.



© 2026 The Authors. Published by Solutiva PetroTechno Journal (SPTJ). This is an open access article under the CC BY license (<https://creativecommons.org/licenses/by/4.0/>)

INTRODUCTION

Well cementing is one of the important stages in oil and gas drilling operations, serving to provide support for the casing, prevent fluid migration between formations, and maintain well integrity during drilling and production operations (American Petroleum Institute, 2021; Nelson & Guillot, 2021). The success of the cementing process is strongly influenced by the quality of the cement used, particularly its ability to withstand compressive loads (compressive strength) and form a strong bond with the casing (shear bond strength). These two parameters play an important role in maintaining the stability of the cementing structure, thereby reducing the risk of cementing failure that may affect operational safety and well productivity.

API Class G well cement is commonly used in cementing operations because it has characteristics suitable for various well conditions and can be combined with various types of additives (API, 2019). Additives are incorporated to improve the physical and mechanical properties of cement according to operational requirements. One approach that is currently being widely developed is the utilization of pozzolanic materials from agricultural waste as alternative additives. In addition to its potential to improve cement performance, the utilization of agricultural waste also supports the concept of more sustainable and environmentally friendly resource utilization (Scrivener et al., 2018; Juenger et al., 2019).

Pozzolanic materials contain reactive silica that can react with calcium hydroxide produced during cement hydration and form calcium silicate hydrate (C-S-H). C-S-H is the primary hydration product that contributes to increased strength and density of the cement structure (Mehta & Monteiro, 2014). Therefore, various agricultural wastes with high silica content have been widely investigated as cement additives, one of which is sugarcane leaf ash. Sugarcane leaf ash has potential as a pozzolanic

material and is therefore expected to improve the mechanical properties of cement when used at an appropriate concentration.

Several previous studies have shown that sugarcane ash-based materials can improve cement material performance at certain contents. Bahurudeen et al. (2015) reported that the use of sugarcane ash could improve the mechanical properties of cement materials through pozzolanic activity. Cordeiro and Kurtis (2017) also stated that the characteristics and fineness of sugarcane ash affect its pozzolanic reactivity and cement material performance. In addition, Bayapureddy et al. (2023) showed that adding sugarcane ash at an optimum content could increase compressive strength, whereas excessive amounts caused a decrease in the mechanical properties of the material.

Although many studies have investigated the utilization of sugarcane-based ash, most have focused on applications in concrete or construction cement. Research on the use of sugarcane leaf ash as an additive in API Class G well cement, particularly studies that simultaneously evaluate compressive strength and shear bond strength, remains relatively limited. Therefore, research is needed to provide information on the effect of adding sugarcane leaf ash on the mechanical properties of well cement as an alternative additive derived from agricultural waste.

This study aims to analyze the effect of adding sugarcane leaf ash at concentrations of 0%, 1%, 2%, 3%, and 4% by weight of cement (BWOC) on the compressive strength and shear bond strength of API Class G well cement. The results are expected to provide information on the optimum concentration of sugarcane leaf ash for improving the mechanical properties of well cement and to serve as a reference for developing alternative additives utilizing agricultural waste for oil and gas well cementing applications.

RESEARCH METHODS

This study used a laboratory experimental method to analyze the effect of adding sugarcane leaf ash on the mechanical properties of API Class G well cement. The independent variable was the concentration of sugarcane leaf ash at 0%, 1%, 2%, 3%, and 4% by weight of cement (BWOC), while the dependent variables were compressive strength and shear bond strength. All research activities were conducted at the Petroleum Engineering Laboratory of STT Migas Balikpapan, referring to well cement testing procedures based on API Recommended Practice 10B-2 (American Petroleum Institute, 2021).

The materials used in the study consisted of API Class G well cement, mixing water, and sugarcane leaf ash as an additive. The equipment used included a digital scale, mixer, specimen molds, water bath, and hydraulic press. The mixture composition for each sample variation is presented in Table 1.

Table 1 Composition of the Research Sample Mixtures

Sample Variation	API Class G Cement (g)	Sugarcane Leaf Ash (% BWOC)	Sugarcane Leaf Ash (g)	Water (mL)
0%	350	0	0	154
1%	350	1	3.5	154
2%	350	2	7	154
3%	350	3	10.5	154
4%	350	4	14	154

Each sample was prepared using 350 g of API Class G cement and 154 mL of mixing water, while the amount of sugarcane leaf ash was adjusted according to the specified concentration variations, namely 0%, 1%, 2%, 3%, and 4% BWOC. All materials were weighed according to the mixture composition and then mixed using a mixer until a homogeneous slurry was obtained. The slurry was subsequently poured into the specimen molds and cured using a water bath according to laboratory procedures.

After the *curing* process was completed, the specimens were tested using a hydraulic press to obtain compressive strength and shear bond strength values. The values obtained for each sample variation were then analyzed descriptively by comparing changes in the two parameters with increasing sugarcane leaf ash concentration. The analysis results are presented in tables and graphs to evaluate the effect of adding sugarcane leaf ash on the mechanical properties of API Class G well cement and to determine the concentration that provides optimum performance.

RESULTS AND DISCUSSION

Compressive strength testing was conducted to determine the ability of API Class G well cement to withstand compressive loads after the addition of sugarcane leaf ash as an additive. This parameter is one of the main indicators of the success of the cementing process because it is related to the ability of the cement to maintain casing structural integrity and prevent fluid leakage during drilling and production operations (API, 2021; Nelson & Guillot, 2021). The compressive strength test results for each sugarcane leaf ash concentration are presented in Table 2.

Table 2 Compressive Strength Test Results

Sugarcane Leaf Ash Concentration (% BWOC)	Compressive Strength (psi)
0	372.52
1	248.34
2	629.86
3	153.40
4	372.52

Based on Table 2, the addition of sugarcane leaf ash affected the compressive strength of API Class G well cement. The compressive strength varied at each concentration, indicating that the material response to the addition of sugarcane leaf ash was not linear.

The sample without sugarcane leaf ash (0% BWOC) produced a compressive strength of 372.52 psi and was used as the reference value. The addition of 1% BWOC sugarcane leaf ash decreased the compressive strength to 248.34 psi. At a concentration of 2% BWOC, the compressive strength increased to 629.86 psi, which was the highest value, approximately 69.1% higher than that of the cement without additives.

This increase indicates that, at a certain concentration, sugarcane leaf ash contributes positively to improving the mechanical properties of well cement through the pozzolanic reaction. However, when the concentration was increased to 3% BWOC, the value decreased to 153.40 psi and then increased again at 4% BWOC (372.52 psi), but did not exceed the optimum point at 2% BWOC. This relationship is visualized in Figure 1.

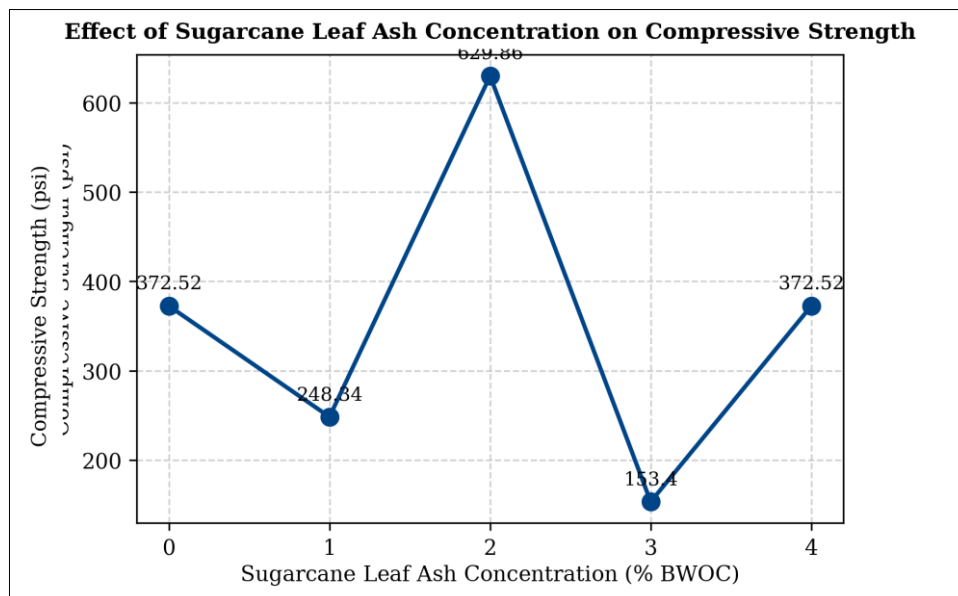


Figure 1 Relationship between Sugarcane Leaf Ash Concentration and Compressive Strength

The curve profile in Figure 1 represents the sensitivity of API Class G well cement hydration to the addition of pozzolanic material. The peak of the curve at a concentration of 2% BWOC indicates a balance point in the reaction kinetics between the availability of calcium hydroxide ($\text{Ca}(\text{OH})_2$) and

the silica reactivity of sugarcane leaf ash. However, the significant decrease after exceeding this optimum point confirms the occurrence of a *dilution effect*. Under these conditions, the reduced proportion of pure Portland cement caused by excessive additive addition can no longer be compensated for by the rate of secondary calcium silicate hydrate (C-S-H) gel formation. In addition, excess sugarcane leaf ash particles that do not participate in the reaction may become *weak points* within the cement matrix, thereby disrupting structural homogeneity and drastically reducing the mechanical integrity of the cement.

Shear bond strength testing aims to evaluate the shear bond strength between the cement and casing. A strong bond is essential for supporting casing loads and preventing formation fluids from migrating through the annulus (Nelson & Guillot, 2021). The shear bond strength test results with the addition of sugarcane leaf ash are presented in Table 3.

Table 3 Shear Bond Strength Test Results

Sugarcane Leaf Ash Concentration (% BWOC)	Shear Bond Strength (psi)
0	950.50
1	1,102.13
2	1,102.13
3	845.20
4	720.10

Based on Table 3, the addition of sugarcane leaf ash significantly affected the shear bond strength of the cement. The control sample (0% BWOC) had a shear bond strength of 950.50 psi. The addition of 1% and 2% BWOC sugarcane leaf ash consistently produced the highest shear bond strength value, reaching 1,102.13 psi, indicating that within this concentration range, the interaction among cement particles, the additive, and the casing surface was optimal.

However, increasing the sugarcane leaf ash concentration beyond 2% BWOC caused a decrease in bond strength. At concentrations of 3% and 4% BWOC, the shear bond strength decreased to 845.20 psi and 720.10 psi, respectively. This decrease is presumed to occur because of excess pozzolanic material that does not participate in the reaction, triggering the formation of microvoids or agglomeration that reduces the effective contact area and adhesion between the cement and casing (Mehta & Monteiro, 2014). This fluctuation in values is illustrated in Figure 2.

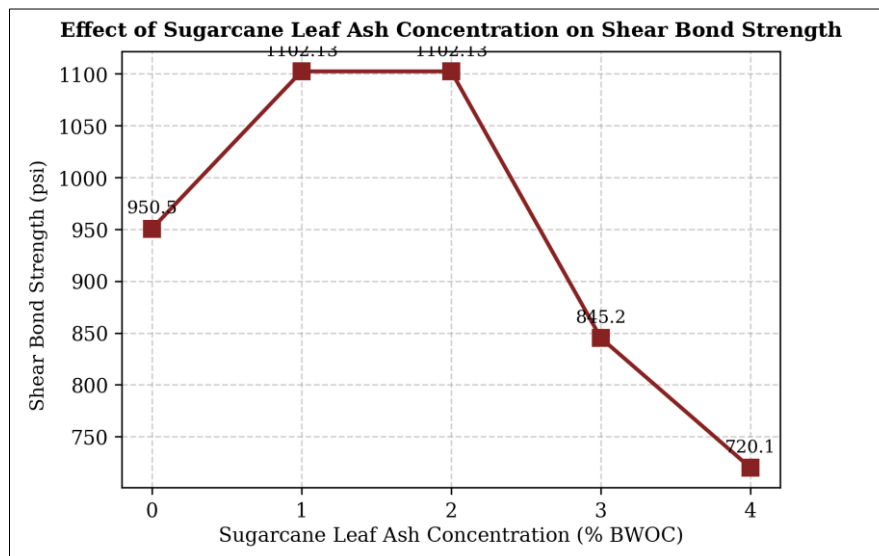


Figure 2 Relationship between Sugarcane Leaf Ash Concentration and Shear Bond Strength

In contrast to the *compressive strength* trend, the curve in Figure 2 shows that *shear bond strength* has an optimum tolerance range represented by a *plateau* at concentrations of 1% and 2%

BWOC. The achievement of the maximum value within this range indicates that sugarcane leaf ash not only supports the pozzolanic reaction but also provides a *micro-filler effect*. This effect can densify the *interfacial transition zone* (ITZ) between the cement matrix and the *casing* surface. Conversely, the consistent decrease in strength at concentrations of 3% and 4% BWOC confirms that excessive additive concentrations can trigger particle agglomeration. Such agglomeration increases local porosity and inhibits wetting or direct contact between the cement paste and the *casing* wall, thereby significantly reducing adhesion and *shear bond strength*.

CONCLUSION

The addition of sugarcane leaf ash significantly affected the mechanical properties of API Class G well cement. The test results showed that the highest compressive strength reached 629.86 psi at a concentration of 2% BWOC, while the highest shear bond strength of 1,102.13 psi was achieved at concentrations of 1% and 2% BWOC. Adding sugarcane leaf ash above 2% BWOC caused a decrease in both mechanical parameters due to excess material that was not optimally hydrated. Overall, a concentration of 2% BWOC was established as the optimum limit for the most effective use of sugarcane leaf ash in improving the quality of well cement.

REFERENCES

- American Petroleum Institute. (2019). *Specification for cements and materials for well cementing* (API Specification 10A, 25th ed.). American Petroleum Institute.
- American Petroleum Institute. (2021). *Recommended practice for testing well cements* (API Recommended Practice 10B-2, 2nd ed.). American Petroleum Institute.
- Bahurudeen, A., Santhanam, M., & Gokul Dev, V. (2015). Performance evaluation of sugarcane bagasse ash blended cement in concrete. *Cement and Concrete Composites*, 59, 77–88.
- Bayapureddy, Y., Reddy, P. S., & Rao, G. V. (2023). Characteristic evaluation of concrete containing sugarcane bagasse ash. *Results in Engineering*, 20, Article 101506.
- Cordeiro, G. C., & Kurtis, K. E. (2017). Effect of mechanical processing on sugar cane bagasse ash pozzolanicity. *Cement and Concrete Research*, 97, 41–49.
- Juenger, M. C. G., Snellings, R., & Bernal, S. A. (2019). Supplementary cementitious materials: New sources, characterization, and performance insights. *Cement and Concrete Research*, 122, 257–273.
- Mehta, P. K., & Monteiro, P. J. M. (2014). *Concrete: Microstructure, properties, and materials* (4th ed.). McGraw-Hill Education.
- Nelson, E. B., & Guillot, D. (2021). *Well cementing fundamentals*. Schlumberger.
- Scrivener, K. L., John, V. M., & Gartner, E. M. (2018). Eco-efficient cements: Potential economically viable solutions for a low-CO₂ cement-based materials industry. *Cement and Concrete Research*, 114, 2–26.