

Effect of sodium chloride additive on the compressive strength of API class G oil well cement

Hendy¹, Rohima Sera Afifah¹, Nuruddin Kafy El-Ridlo¹, Arum Sekar Kinasih Mergi Saputri¹

¹ Sekolah Tinggi Teknologi Minyak dan Gas Bumi Balikpapan

Correspondence: hendydy98@gmail.com

Article Info

Article history:

Received Jun 12th, 2026

Revised Aug 26th, 2026

Accepted Aug 29th, 2026

Keyword:

API Class G cement; compressive strength; hydration; oil well cement; sodium chloride (NaCl)

ABSTRACT

Oil well cement plays a critical role in maintaining well integrity by providing mechanical support to the casing and preventing fluid migration between geological formations. This study investigated the effect of sodium chloride (NaCl) as an additive on the compressive strength of API Class G oil well cement. An experimental laboratory method was employed using six NaCl concentrations of 0%, 1%, 2%, 3%, 4%, and 5% by weight of cement (BWOC). Cement slurry specimens were prepared with a constant cement mass of 350 g and 154 mL of water, cured for 24 hours, and tested using a hydraulic press to determine their compressive strength. The results showed that the addition of NaCl significantly influenced the compressive strength of the cement. The compressive strength decreased from 372.52 psi for the control sample to 310.43 psi at 1% NaCl, increased to 460.24 psi at 2% and 606.43 psi at 3%, declined to 381.19 psi at 4%, and reached the highest value of 656.41 psi at 5% NaCl. These findings indicated that NaCl acted as a hydration accelerator at appropriate concentrations, promoting the formation of a denser cement matrix and improving compressive strength. Under the experimental conditions of this study, the optimum NaCl concentration for enhancing the compressive strength of API Class G oil well cement was 5% BWOC.



© 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

Oil well cementing is one of the most critical operations in drilling because it provides zonal isolation, supports the casing, and prevents fluid migration between subsurface formations. A properly designed cement sheath ensures well integrity throughout the operational life of the well by maintaining hydraulic isolation and protecting the casing from formation fluids and corrosive environments (Nelson, 2012). Consequently, the mechanical performance of oil well cement is an essential factor in achieving safe and efficient drilling operations.

API Class G cement is the most commonly used cement for oil and gas well cementing because of its adaptability to various well conditions and its compatibility with different chemical additives. The performance of API Class G cement can be modified by incorporating additives that function as accelerators, retarders, extenders, or weighting agents to satisfy specific operational requirements (Harooni et al., 2025; Gannam et al., 2016). Among these additives, sodium chloride (NaCl) has attracted considerable attention because it can accelerate cement hydration and influence the development of mechanical strength. Chloride ions promote the hydration of cement compounds, particularly tricalcium silicate (C_3S), leading to the formation of calcium silicate hydrate ($C-S-H$), which is primarily responsible for the strength of hardened cement (Sun et al., 2023; Li et al., 2020; Morandau et al., 2014).

Several previous studies have investigated the influence of sodium chloride on the properties of cement. Li et al. (2020) reported that the presence of sodium chloride affected the hydration process, microstructure, and mechanical properties of cementitious materials. Costa et al. (2018) demonstrated that the hydration period significantly influenced the carbonation resistance and mechanical performance of oil well Portland cement. Furthermore, da Silva et al. (2023) observed that the addition of sodium chloride altered the degradation behavior of oil well cement exposed to supercritical carbon dioxide, indicating that NaCl concentration plays an important role in determining cement performance under different operating conditions.

Although the effect of sodium chloride on cement hydration has been widely reported, previous studies have presented inconsistent results regarding its influence on compressive strength. Several researchers reported that appropriate NaCl concentrations enhanced early-age strength by accelerating hydration, whereas higher concentrations could adversely affect the cement microstructure because of excessive hydration rates and non-uniform hydration products (Li et al., 2020). These findings indicate that the optimum sodium chloride concentration depends on the cement composition, curing conditions, and experimental procedures. Therefore, further investigation is required to evaluate the effect of different NaCl concentrations on the compressive strength of API Class G oil well cement under controlled laboratory conditions.

The novelty of this study lies in the systematic evaluation of six sodium chloride concentrations (0%, 1%, 2%, 3%, 4%, and 5% by weight of cement) on the compressive strength of API Class G oil well cement using identical slurry compositions, curing conditions, and testing procedures. This approach enables a direct comparison of the influence of NaCl concentration on the mechanical performance of the cement and facilitates the identification of the optimum concentration for strength enhancement.

Therefore, this study aimed to evaluate the effect of sodium chloride as an additive on the compressive strength of API Class G oil well cement and to determine the NaCl concentration that produced the highest compressive strength under the experimental conditions employed. The results of this study are expected to provide experimental data that may contribute to the optimization of cement slurry formulations for oil and gas well cementing operations.

RESEARCH METHODS

This study employed an experimental laboratory method to investigate the effect of sodium chloride (NaCl) as an additive on the compressive strength of API Class G oil well cement. The research was conducted at the Petroleum Engineering Laboratory of Sekolah Tinggi Teknologi Minyak dan Gas (STT Migas) Balikpapan. Primary data were obtained through laboratory testing, while supporting information was collected from scientific journals, books, and relevant standards related to oil well cementing.

API Class G oil well cement, sodium chloride (NaCl), and distilled water were used as the primary materials in this study. Six cement slurry formulations were prepared by varying the NaCl concentration at 0%, 1%, 2%, 3%, 4%, and 5% by weight of cement (BWOC). Each specimen consisted of 350 g of API Class G cement and 154 mL of distilled water, while the amount of sodium chloride was adjusted according to the specified concentration. The composition of each cement slurry is presented in Table 1.

Table 1 Cement Slurry Composition

No	NaCl Concentration (%) BWOC)	API Class G Cement (g)	Sodium Chloride (g)	Water (mL)
1	0%	350	0.0	154
2	1%	350	3.5	154
3	2%	350	7.0	154
4	3%	350	10.5	154
5	4%	350	14.0	154
6	5%	350	17.5	154

The cement slurry was prepared by first weighing the required quantities of cement and sodium chloride using a calibrated digital balance. The dry materials were mixed uniformly before being added to the mixing water. Mechanical mixing was performed using a laboratory cement mixer following the experimental procedure established for oil well cement preparation to obtain a homogeneous slurry. The slurry was subsequently poured into cubic molds for compressive strength testing. After casting, the molds were sealed and cured in a water bath for 24 hours under controlled temperature conditions to ensure consistent hydration among all specimens.

After the curing period, the specimens were removed from the molds and tested using a hydraulic press. The applied compressive load was gradually increased until specimen failure occurred, and the maximum load was recorded (API, 2013). The hydraulic press readings, expressed in US tons, were converted into pounds (lb), after which the compressive strength values were calculated in pounds per square inch (psi). The compressive strength calculation considered the specimen dimensions, bearing block area, loading area, and correction factor (K) determined from the height-to-diameter ratio using linear interpolation when necessary, following the calculation procedure applied in this study.

The compressive strength values obtained for each NaCl concentration were compared to evaluate the influence of sodium chloride on the mechanical performance of API Class G oil well cement. The experimental results were then analyzed to identify the concentration that produced the highest compressive strength and to explain the observed behavior based on the hydration mechanism of cement and previous findings reported in the literature.

RESULTS AND DISCUSSION

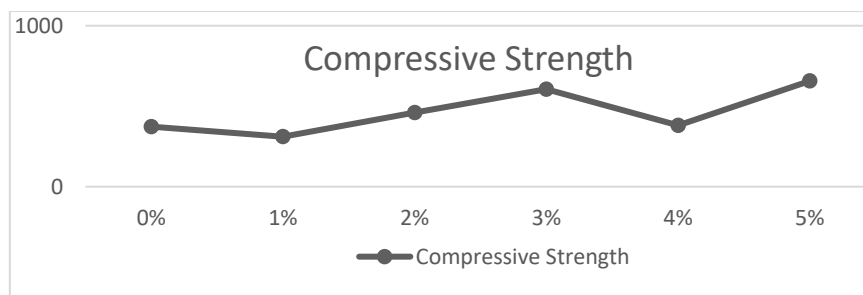
The experimental results showed that the addition of sodium chloride (NaCl) affected the compressive strength of API Class G oil well cement. Six cement slurry formulations containing 0%, 1%, 2%, 3%, 4%, and 5% NaCl by weight of cement (BWOC) were prepared and tested after 24 hours of curing. The compressive strength values obtained from the laboratory tests are presented in Table 2.

Table 2 Compressive Strength of API Class G Oil Well Cement with Various NaCl Concentrations

No	NaCl Concentration (% BWOC)	Compressive Strength (psi)
1	0%	372.52
2	1%	310.43
3	2%	460.24
4	3%	606.43
5	4%	381.19
6	5%	656.41

Table 2 summarizes the compressive strength of API Class G oil well cement after the addition of different sodium chloride concentrations. The results indicate that the compressive strength varied with increasing NaCl concentration, demonstrating that sodium chloride influenced the mechanical behavior of the cement. The compressive strength ranged from 310.43 psi to 656.41 psi, with the lowest value observed at 1% NaCl and the highest value recorded at 5% NaCl. Although the overall trend showed an increase in compressive strength with increasing NaCl concentration, a reduction was observed at 4% NaCl, indicating that the influence of sodium chloride on compressive strength was not linear. This behavior suggests that the effectiveness of NaCl as a cement additive depended on its concentration and its effect on the cement hydration process.

To provide a clearer representation of this behavior, the variation in compressive strength with increasing NaCl concentration is illustrated in Picture 1, which facilitates further interpretation of the observed trend.



Picture 1 Effect of Sodium Chloride Concentration on the Compressive Strength of API Class G Oil Well Cement

Picture 1 illustrates the variation in the compressive strength of API Class G oil well cement with increasing sodium chloride (NaCl) concentration after 24 hours of curing. The graph shows that the addition of NaCl significantly influenced the compressive strength of the cement; however, the response was non-linear. Compared with the control specimen (0% NaCl), the compressive strength initially decreased at 1% NaCl, increased considerably at 2% and 3% NaCl, declined at 4% NaCl, and subsequently increased to the highest value at 5% NaCl. This fluctuating pattern indicates that the effect of sodium chloride on compressive strength depended on its concentration rather than increasing proportionally with the amount of additive.

The increase in compressive strength observed at intermediate NaCl concentrations is likely associated with the role of sodium chloride in accelerating the hydration of cement compounds. During the hydration process, tricalcium silicate (C_3S) reacts with water to form calcium silicate hydrate ($C-S-H$), which is the primary hydration product responsible for the strength and integrity of hardened cement (Taylor, 1997). Previous studies have reported that chloride ions can accelerate the early hydration process and promote the formation of hydration products, thereby improving the mechanical properties of cementitious materials under appropriate conditions (Li et al., 2020; Martha et al., 2015). Therefore, the increase in compressive strength observed in this study at 2% and 3% NaCl may be attributed to a more effective hydration process that produced a denser cement matrix.

Conversely, the decrease in compressive strength at 4% NaCl suggests that the beneficial effect of sodium chloride was not sustained at all concentrations (Salehi et al., 2015). Li et al. (2020) reported that excessive chloride content may alter hydration kinetics and influence the development of the cement microstructure, potentially resulting in non-uniform hydration products and localized porosity. Although the present study did not include microstructural characterization, the reduction in compressive strength observed at 4% NaCl may indicate that the hydration process at this concentration was less favorable for strength development. This interpretation is consistent with the findings of Costa et al. (2018), who emphasized that the progression of cement hydration plays a significant role in determining the resulting microstructure and mechanical properties.

When the NaCl concentration was increased to 5% BWOC, the compressive strength reached 656.41 psi, representing the highest value obtained in this study. Under the laboratory conditions employed, this result suggests that the selected NaCl concentration provided more favorable conditions for early strength development than the other concentrations investigated. Similar observations have been reported by da Silva et al. (2023), who demonstrated that variations in sodium chloride content significantly influence the behavior and performance of oil well cement depending on the curing and exposure conditions.

Overall, Picture 1 demonstrates that sodium chloride significantly affected the compressive strength of API Class G oil well cement. However, the observed response was concentration-dependent, indicating that increasing the amount of sodium chloride did not consistently result in higher compressive strength. These findings highlight the importance of determining an optimum NaCl concentration to achieve improved mechanical performance while maintaining stable hydration behavior. A more detailed discussion of the compressive strength obtained at each NaCl concentration is presented in the following section.

CONCLUSION

The addition of sodium chloride (NaCl) significantly influenced the compressive strength of API Class G oil well cement after 24 hours of curing. The experimental results demonstrated that the effect of NaCl concentration on compressive strength was non-linear. Compared with the control specimen, the compressive strength decreased at 1% NaCl, increased substantially at 2% and 3% NaCl, decreased again at 4% NaCl, and reached the highest value of 656.41 psi at 5% NaCl. These results indicate that the effectiveness of sodium chloride as a cement additive depended on its concentration, as different concentrations produced different hydration responses and mechanical performance. Under the experimental conditions employed in this study, the addition of 5% NaCl by weight of cement (BWOC) provided the optimum compressive strength of API Class G oil well cement. The findings contribute to a better understanding of the influence of sodium chloride on the compressive strength of oil well cement and provide experimental data that may be used as a reference for optimizing cement slurry formulations in petroleum well cementing applications.

REFERENCES

- API. (2013). *API recommended practice 10B-2: Recommended practice for testing well cements* (2nd ed.). American Petroleum Institute.
- Costa, B. L. de S., Freitas, J. C. O., Andrade, H. M. C., & Silva, A. A. (2018). Carbonation in oil well Portland cement: Influence of hydration time prior to contact with CO₂. *Construction and Building Materials*, 159, 252–260.
- da Silva, A. C. O., Miranda, H. B., Andrade, H. M. C., Vieira de Melo, S. A. B., & Gonçalves, J. P. (2023). Degradation of oil well cement with sodium chloride content exposed to supercritical carbon dioxide conditions: Temperature and pressure effects. *Journal of Petroleum Science and Engineering*, 220, 111198.
- Gannam, M. G., Rossi, L., Gregatti, A., Khalfallah, I., Azwar, C., Aslan, J., ... & Campos, G. (2016). Best Laboratory Procedures Beyond API Recommendations for Improving Deepwater Liner Cementing. In *Offshore Technology Conference Asia*.
- Harooni, A. B., Maroof, H., Khoshmardan, M. A., & Pourali, O. (2025). A novel predictive model for the compressive strength development in Class G cement slurries at different temperatures, retarder, and salt concentrations. *Case Studies in Construction Materials*, 22, e04360.
- Li, P., Li, W., Yu, T., Qu, F., & Tam, V. W. (2020). Investigation on early-age hydration, mechanical properties and microstructure of seawater sea sand cement mortar. *Construction and Building Materials*, 249, 118776.
- Martha, B. I., Zabidi, L., & Satiawati, L. (2015). Studi laboratorium pengaruh penambahan lignosulfonate pada compressive strength dan thickening time pada semen pemboran kelas G. In *Seminar Nasional Cendekiawan 2015*. Trisakti University.
- Morandau, A., Thiery, M., & Dangla, P. (2014). Investigation of the carbonation mechanism of CH and C–S–H in terms of kinetics, microstructure changes and moisture properties. *Cement and Concrete Research*, 56, 153–170.
- Nelson, E. B. (2012). Well cementing fundamentals. *Oilfield Review*, 24(2), 59–60.
- Salehi, S., Nygaard, R., Weideman, B., et al. (2015). Experimental study of salt content effect on Class G cement properties with application to well integrity. *Energy Procedia*, 76, 519–529.
- Sun, L., Pang, X., Ghabezloo, S., & Yan, H. (2023). Modeling the hydration, viscosity and ultrasonic property evolution of Class G cement up to 90 °C and 200 MPa by a scale factor method. *Petroleum Science*, 20(4), 2372–2385.
- Taylor, H. F. W. (1997). *Cement chemistry* (2nd ed.). Thomas Telford.