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EFFECT OF CONCENTRATED POTASSIUM ALUM WATER ON THE PROPERTIES OF CONCRETE

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ABSTRACT

Potassium alum is an aluminum and sulphate compound. When added to the concrete mixing water, it accelerates the cement hydration. This paper is aimed at investigating the influence of concentrated potassium alum water on the properties of concrete. To achieve the research objectives, potassium alums were milled to powder form and were dissolved in water at different proportions of 2.5%, 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, and 20% relative to the water/cement ratio of 0.6. Then the dissolved water solution was used as mixing water. A total of ninety-eight concrete cubes of 150 x 150 x 150 mm in accordance with BS EN 12390-2 were produced with potassium alum solution at different proportions of 2.5%, 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, and 20%. Also, twelve (12) concrete cubes produced with clean mixing water were used as a benchmark for samples produced with concentrated alum water. Mix ratio of 1:2:4 was adopted. The concrete cube specimens were cured according to BS EN 12390-2 and were preserved from dehydration. All the samples (108) were tested for failure at 7, 14, 21, and 28 days. Results confirmed that 1 to 2.5% addition of potassium alum into the mixing water improved the compressive strength (CS) by 3%. Potassium-concentrated alum water reduces initial CS. An increase in potassium alum content results in a decrease in workability and CS and the reduction in workability is attributed to the high mixing water demand for potassium alum. Potassium alum absorbs water more than Portland limestone cement.

Keywords: *Concrete, Compressive strength, Alum, mixing water, Workability*

1.0 INTRODUCTION

One of the most widely utilized man-made construction materials ever since it was produced is cement concrete, and there has been a significant demand each year for the raw materials used to produce cement concrete, which leads to intensive natural resource exploration. Attempts have been made to recycle environmentally friendly materials across the globe to produce high-strength, durable, and cost-effective concrete. Therefore, finding innovative technology for the building business is thus continually promoted. The quest for improving concrete strength is a significant subject in structural engineering. There is a thorough evaluation considering nanomaterials in improving civil engineering materials. Global efforts to reduce carbon dioxide emissions into the atmosphere have increased during the past twenty years. Due to the replacement of cement with other cementitious materials in concrete production, the cement production process contributes about 5% of all emission sources (Jayant, 2013). According to the author, the additives had considerable impacts on the mechanical properties of concrete. Concrete has continuously drawn the attention of scholars as a result of its adaptability to various development conditions and application backgrounds of different structural elements. Despite the several advantages, for example, its outstanding compressive strength, and its disadvantages, such as thermal cracking, have instigated several investigations to be conducted on achieving suitable and optimum concrete constituents. The influence of water, cement, fine, and coarse aggregates on the strength properties of concrete has been researched broadly (Kaveh and Khalegi, 2000; Jayant, 2013; Mustafa, 2018; Mustafa, 2018; Al-Gburi, 2015). Furthermore, many studies have focused on the effects of mineral and chemical additives on concrete properties. However, several of these additives, for example, slag and silica fume, produce higher concrete strength (Nwankwo *et al*., 2020; John et al., 2019; Bharatkumar *et al*., 2005; Bhanjaa and Sengupta, 2005; Lam et al., 1998). For example, fly ash has a negative effect, reducing concrete strength (Yazici *et al*., 2012; Babu and Yerramala, 2012; Atiş, 2005; Yazici, 2008).

Zhen *et al*. (2018) looked at the possibility of using stone dust powder as a pozzolanic material to substitute limestone cement in concrete mixes. Investigations were conducted into how adding sandstone powder affected strength properties and the alkali-silica reaction. According to the authors, the addition of stone dust powder improved strength gains.

Mohamed *et al*., (2022) conducted research to ascertain whether it would be practicable to effectively substitute cement with 5, 10, and 15% by weight of alum as an additive. The 2% $CuFe_2O_4$, 10% activated alum, and 90% cement, composite material gives several benefits that are both environmental and financial.

As a result of the increased significance of reusing various types of waste, it is exceptionally beneficial for reducing the environmental effect. Potassium alum ($K_2(SO_4)\cdot Al_2(SO_4)_3\cdot 24H_2O$) is an aluminum and sulphate compound. The potassium alum present in the concrete mix accelerates the cement hydration (Rajin et al, 2015).

Haider *et al*. (2013) examined the high performance of cement concrete using potassium alum sludge. An alum sludge of 2.5 to 15% relative to cement was utilized in their investigation. Viscocrete-2044 was considered a superplasticizer to enhance workability. The strength of the 6% potassium alum sludge addition increases as the curing period increases. The density of concrete containing alum sludge decreases as the percentage replacement increases, whereas the converse is the case for workability.

Bendary and Abadir (2017) conducted several experiments on concrete incorporating alum. Scholars have mixed alum with cement in different proportions: 2.5%, 5%, 7.5%, and 10%. All of these mix proportions were computed relative to the weight of the cement. The results exhibited that the initial setting time was not altered; however, the final setting time was increased by up to 7.5% and significantly reduced after adding extra alum to the cement. The authors reported that adding 7.5% enhances bending strength, split tensile, and compressive strength (CS).

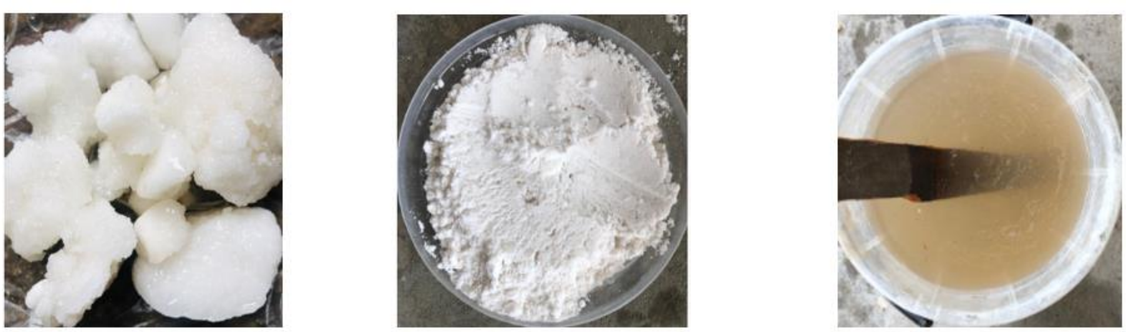
Roszilah and Haider (2013) used alum sludge powder in place of cement. They dried alum sludge and ground it into powder, which was used in concrete at 6%, 9%, 12%, and 15% by weight of cement. They conducted split tensile, flexural, and compressive tests on concrete made with alum sludge for 7 and 28 days to check its feasibility. They concluded that adding 6% alum sludge powder enhances compressive and flexural resistance.

Referring to the previous studies reviewed above, the use of alum in cement concrete has a significant impact on concrete properties, which can improve its mechanical properties. Therefore, adding potassium alum directly to concrete mixing water may be of great significance in the construction industry. This paper investigates the effect of potassium alum-concentrated water on the properties of concrete. The findings are to be evaluated with reference to concrete using clean water.

2.0 MATERIALS AND METHODS

2.1 Materials

The materials considered in this investigation comprises portland limestone cement, potassium alum (PA), water, and fine, and coarse aggregates. The materials considered above in this section are discussed here in detail. Throughout this experiment, Portland limestone cement (Dangote brand) of the 42.5 N grade prescribed by BS EN 197 was employed. As presented in Figure 1(a), potassium alum was sourced from the water treatment plant at Otuoke, Ogbia Local Government Area, Bayelsa State. The aggregates (fine and coarse) used in this investigation were sourced from construction sites within the Niger Delta University campus. The selected particle sizes conform with BS EN 933-1 (2012). Clean water was used for mixing the concrete.



(a) (b) (c)

Figure 1: Potassium alum (a) crystal structure, (b) ground potassium alum, (c) potassium alum solution

2.2 Method

The sourced potassium alums were milled to powder form as depicted in Figure 1 (b), and were dissolved in water at different proportions of 2.5%, 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, and 20% of the mixing water. A water/cement ratio of 0.6 as depicted in (c) was used, and the dissolved solution was used as mixing water. A total of ninety-eight cube samples of 150 x 150 x 150 mm according to BS EN 12390-2 were produced with potassium alum solution at different proportions of 2.5%, 5%, 7.5%, 10%, 12.5%, 15%, 17.5%, and 20%. Also, twelve (12) concrete cubes produced with clean mixing water were used as a benchmark for samples produced with concentrated alum water. In this investigation, a 1:2:4 mix ratio was adopted. The concrete cube specimens were cured in accordance with BS EN 12390-2 and were preserved from dehydration. All the samples (108) were tested for failure at 7, 14, 21, and 28 days.

3.0 RESULTS AND DISCUSSION

3.1 Compressive strength results

Table 1 and Figures 2 to 10 present the findings of the research into the impact of potassium alum-concentrated water on the characteristics of concrete. When designing concrete structural elements, one of the most often utilized concrete parameters by structural engineers is the CS of concrete. The CS of the concrete was evaluated at 7, 14, 21, and 28 days. According to the results presented in Table 1 and Figures 2 to 10, the samples which were produced with potassium alum concentrated water showed reduced initial CS when compared with samples produced with clean water. These findings are similar to those of Gunalaan (2019), which states that in comparison to the reference concrete mix, the substitution of alum sludge at a rate of 5% has enhanced the compressive strength by up to 10%. The concrete samples produced with 2.5% potassium alum concentrated water have shown the highest CS of 32.4 MPa at 28 days, whereas the least CS was observed with the 20% potassium alum concentrated water, which was 16.3 MPa as shown in Table 1. The 2.5% potassium-concentrated water enhanced the compressive strength by 3% as compared with the reference concrete at 28 days. As the addition of potassium alum increases, the compressive strength decreases. The reduction is attributed to poor hydration caused by the alum, as evidently depicted in Figure 2.

Table 1. Compressive strength results

Alum content (%)	7 days strength (Mpa)	14 days strength (Mpa)	21 days strength (Mpa)	28 days strength (Mpa)
0	26.5	28.5	28.8	31.4
2.5	19.0	30.5	31.7	32.4
5.0	16.5	18.0	19.6	23.0
7.5	25.0	26.2	29.2	31.3
10.0	14.7	18.8	19.0	22.9
12.5	18.1	22.2	24.3	25.6
15.0	12.0	18.3	15.5	16.5
17.5	16.2	15.0	16.3	17.0
20.0	11.1	14.4	16.0	16.3

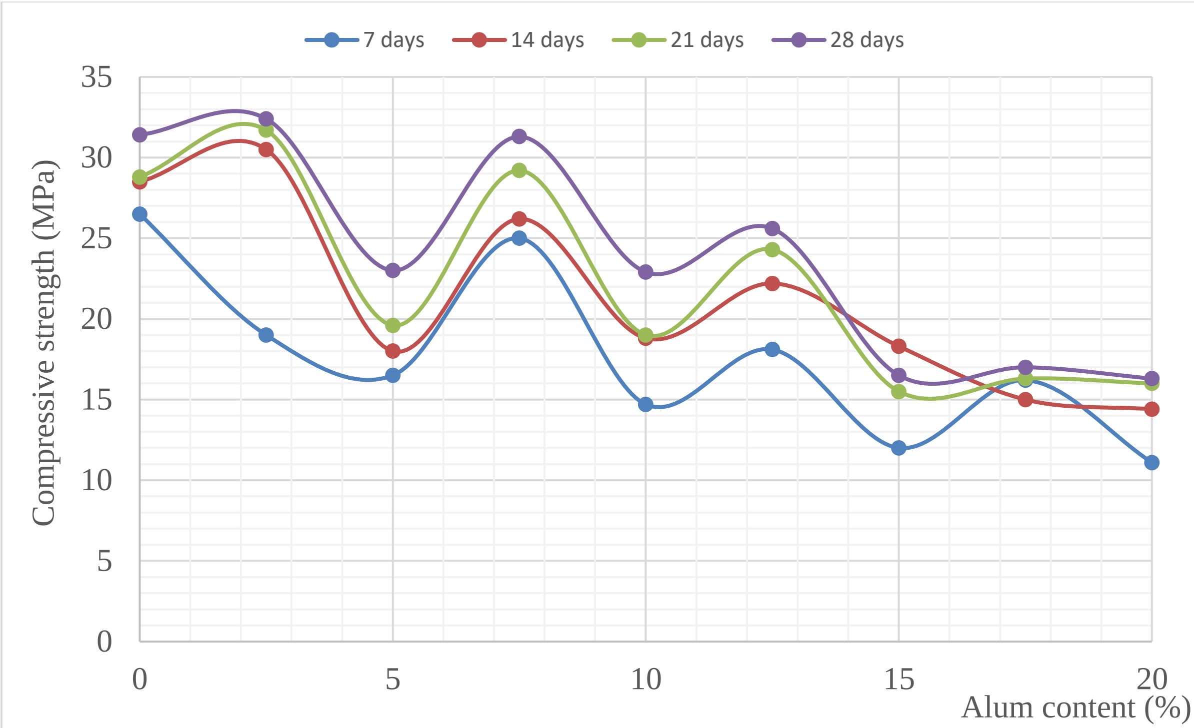


Figure 2: Compressive strength versus alum content

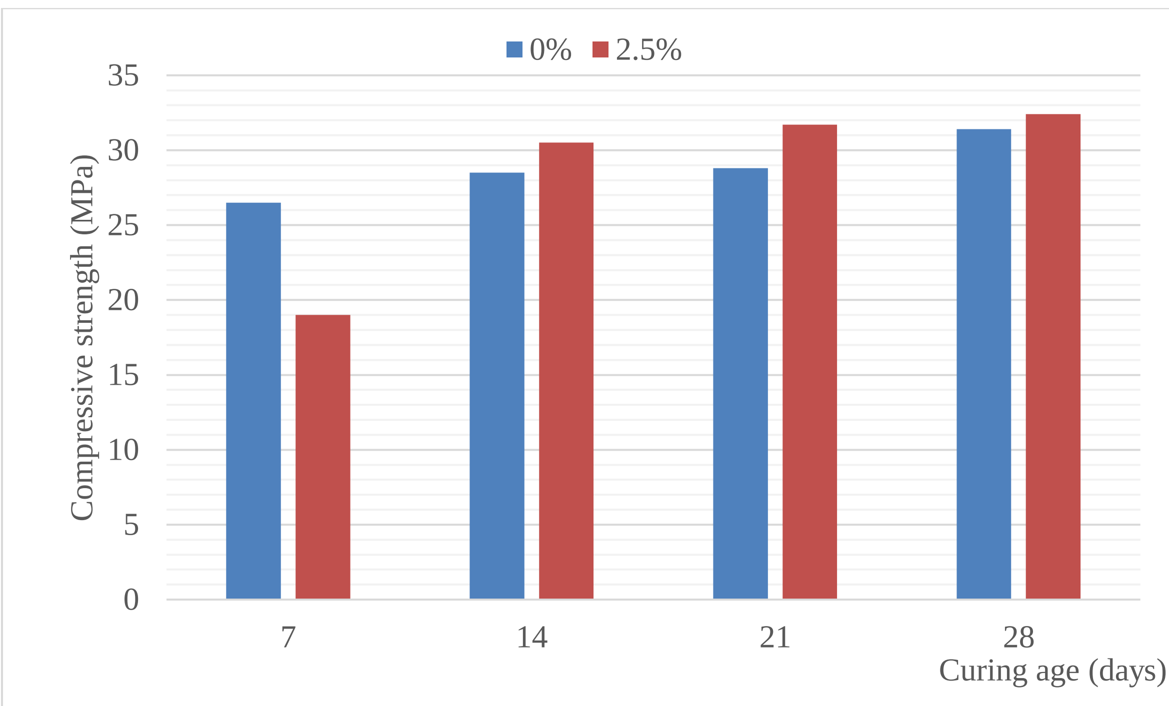


Figure 3: Comparison of the compressive strength of 0% and 2.5%

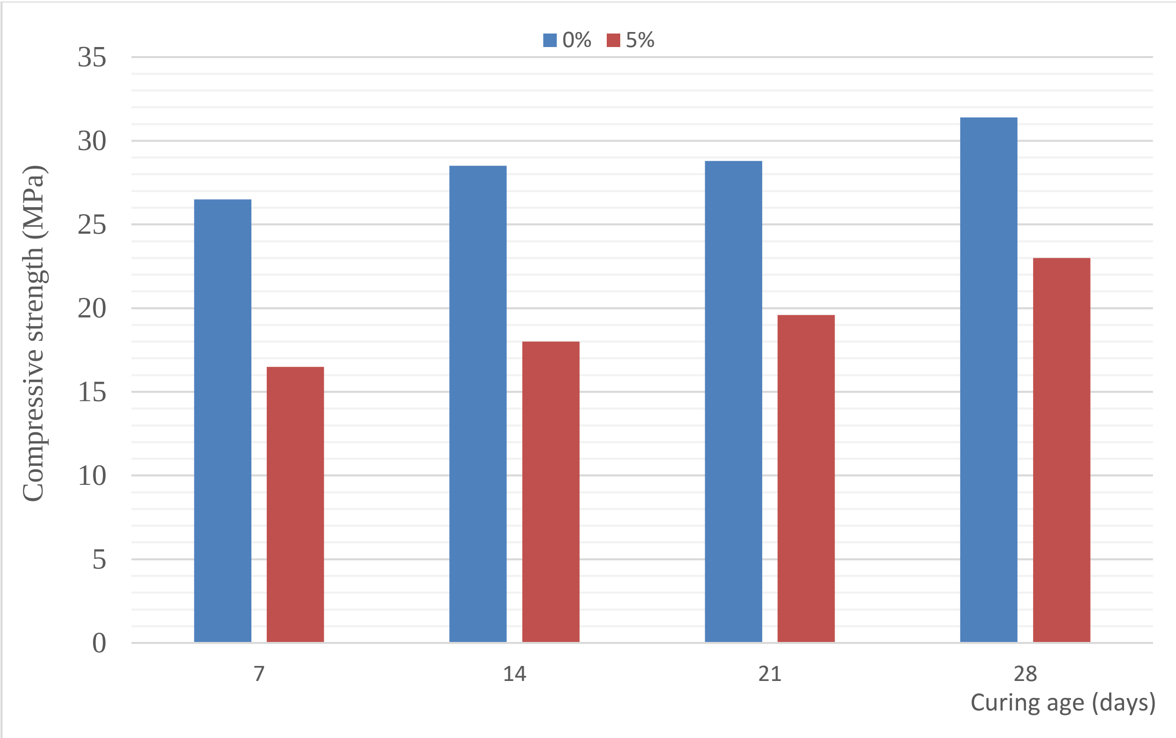


Figure 4: Comparison of the compressive strength of 0% and 5%

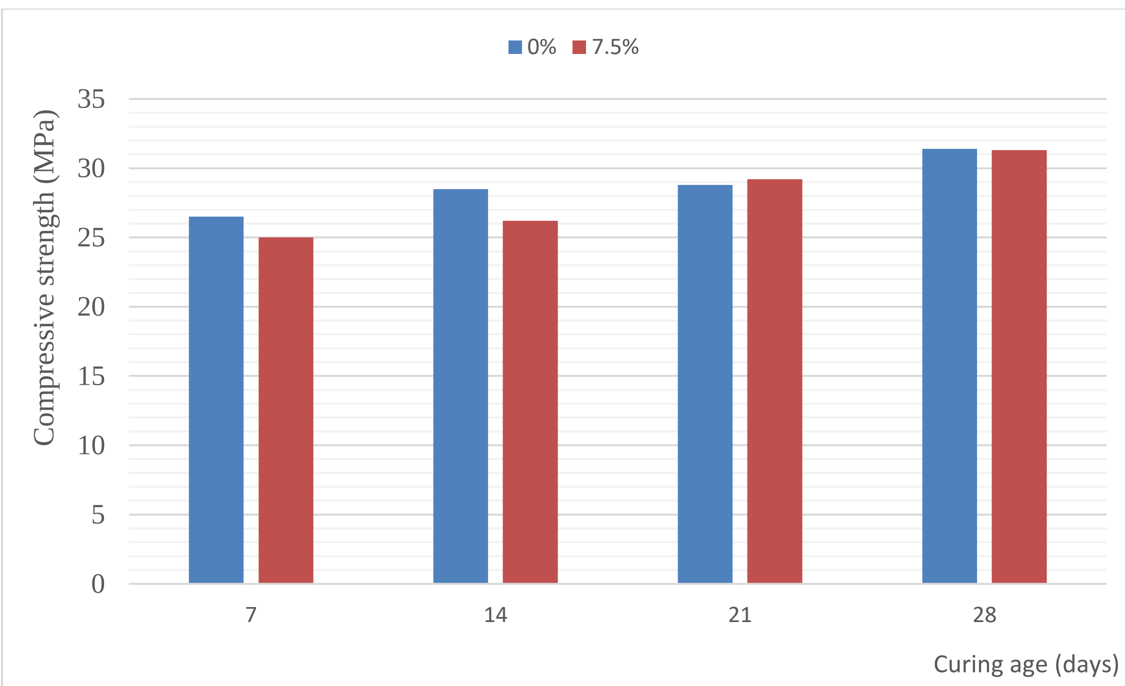


Figure 5: Comparison of the compressive strength of 0% and 7.5%

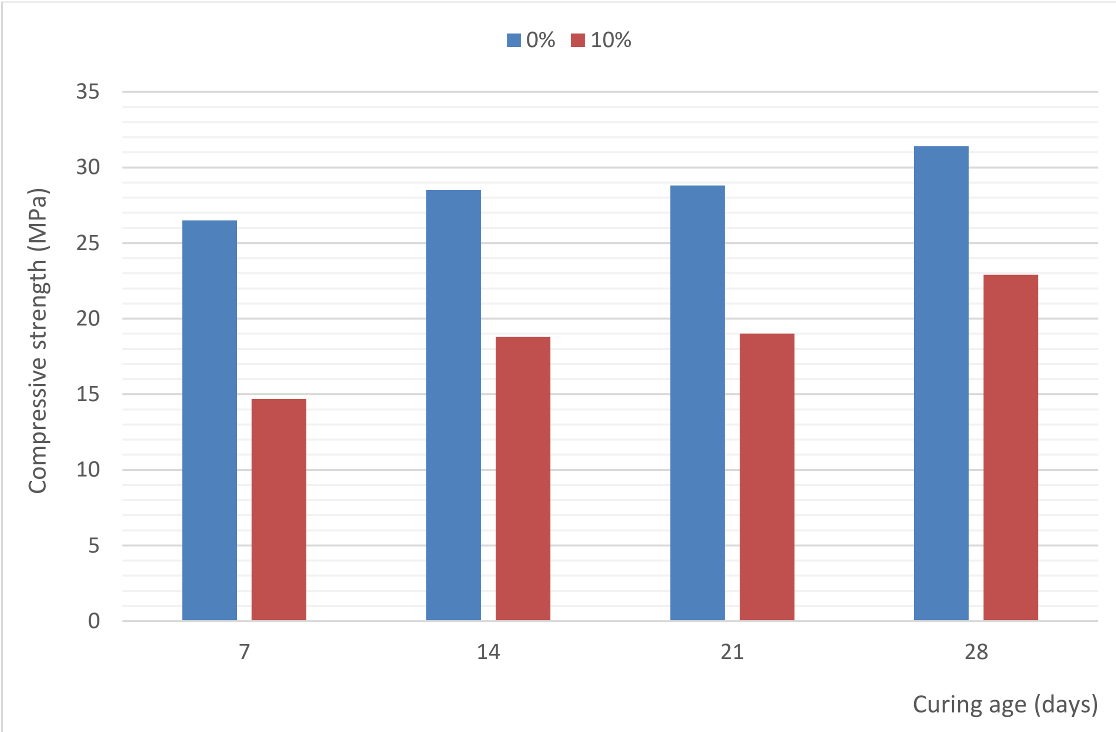


Figure 6: Comparison of the compressive strength of 0% and 10%

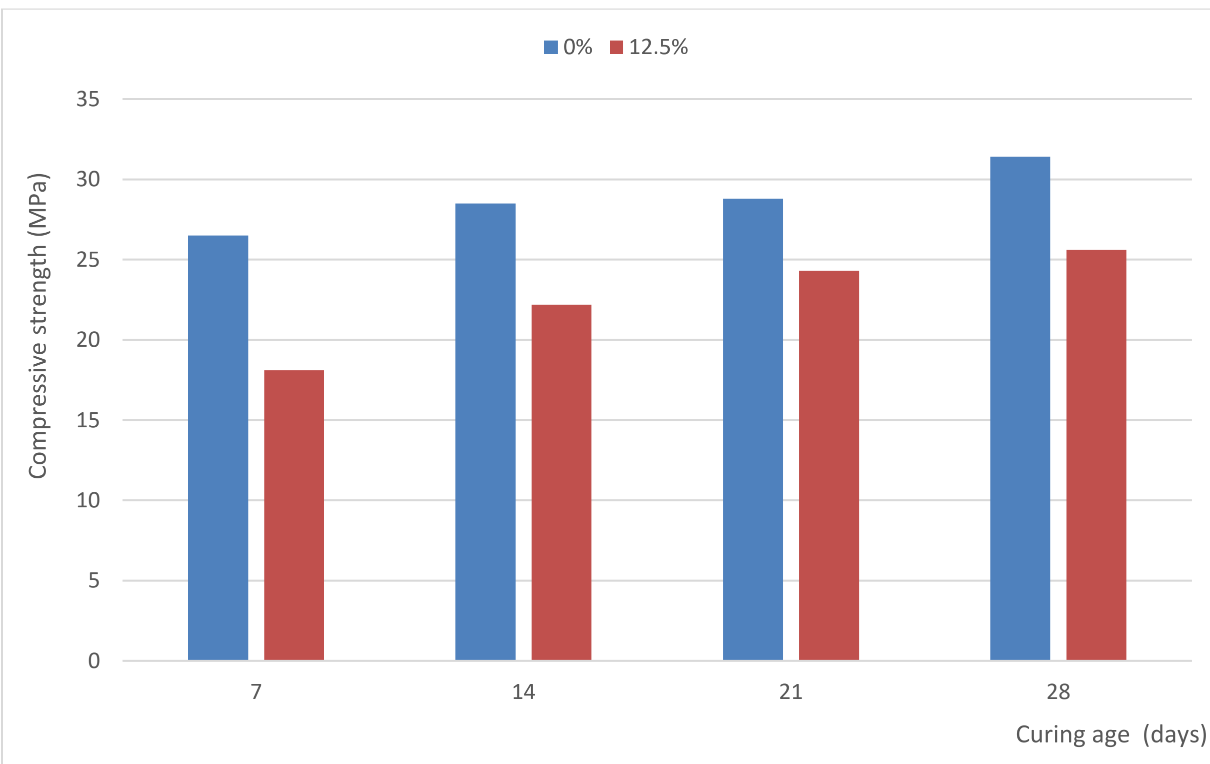


Figure 7: Comparison of the compressive strength of 0% and 12.5%

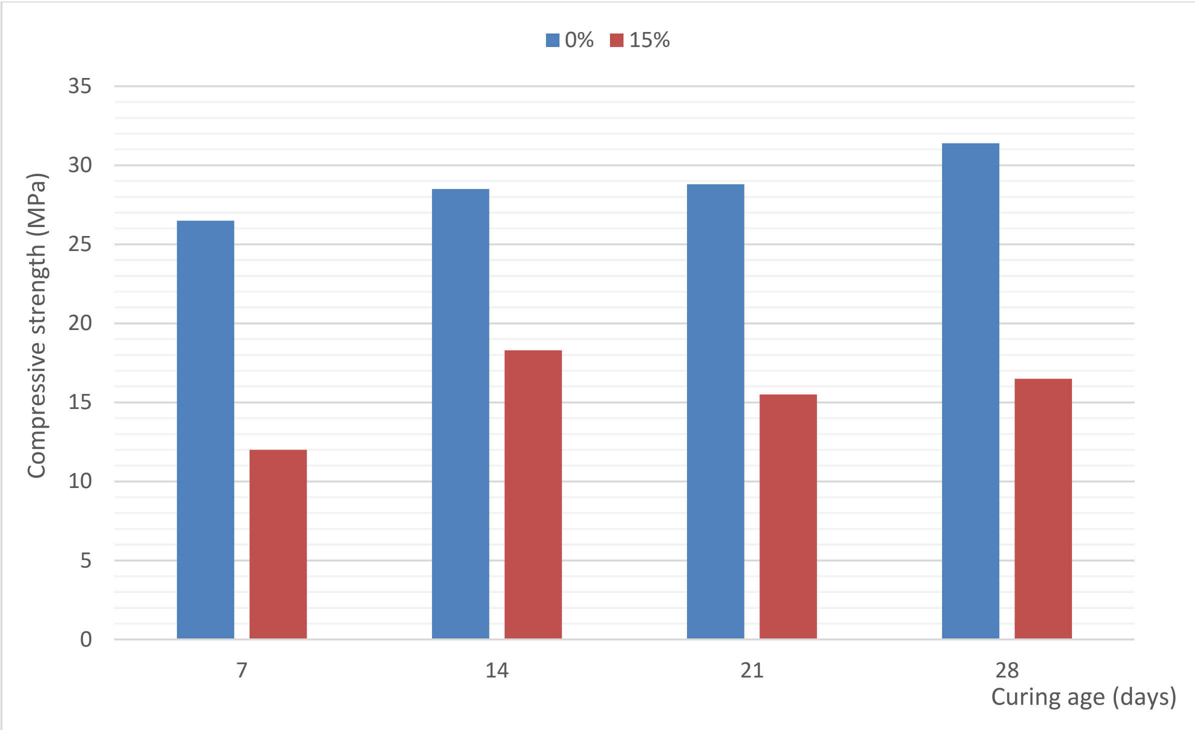


Figure 8: Comparison of the compressive strength of 0% and 15%

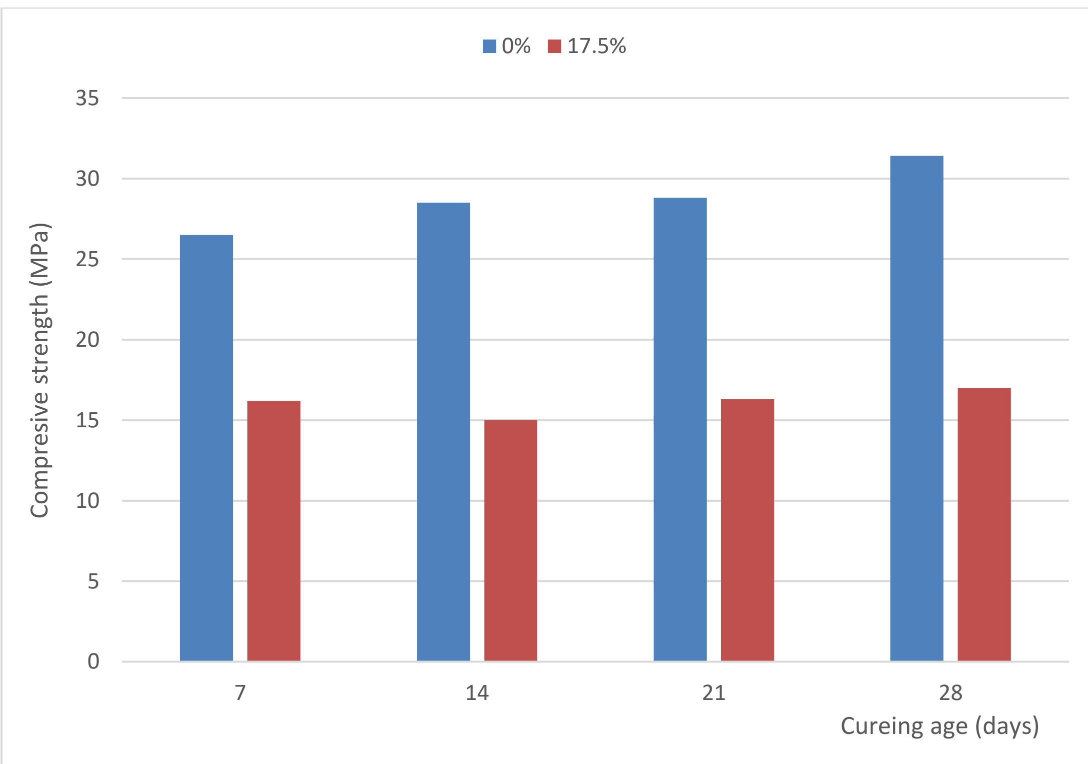


Figure 9: Comparison of the compressive strength of 0% and 17.5%

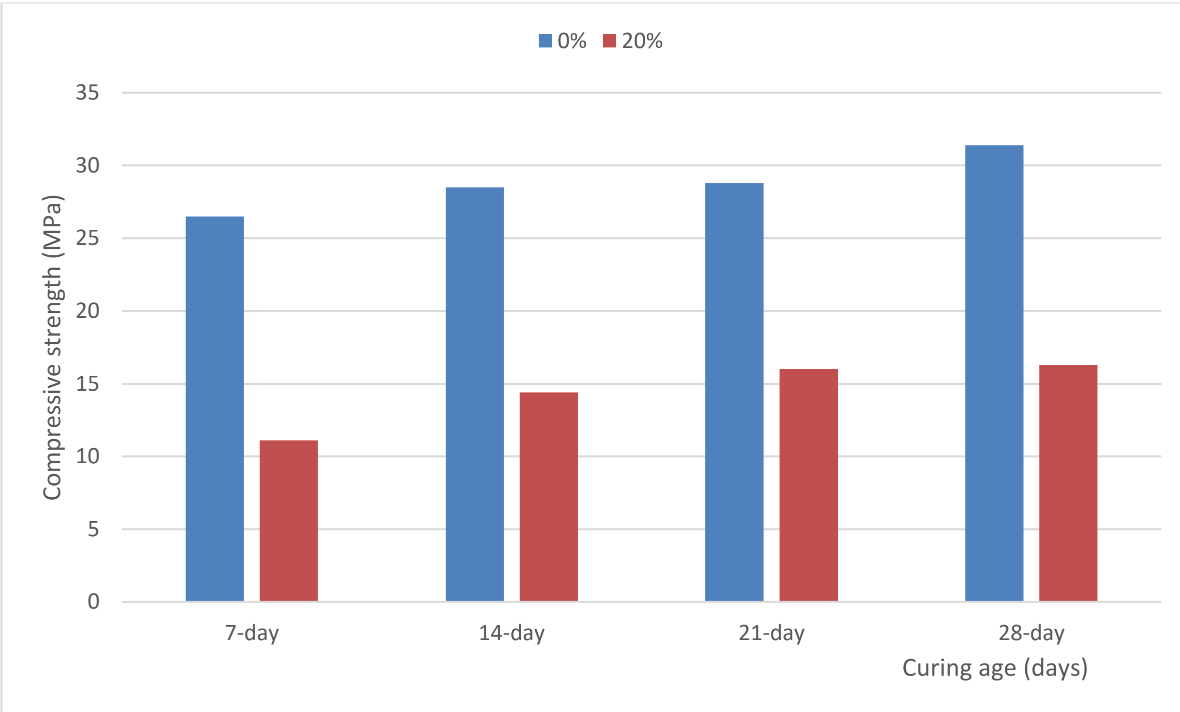


Figure 10: Comparison of the compressive strength of 0% and 20%

3.2 Workability results

Concrete workability is a general term that describes how effortless fresh concrete can be mixed and finished with negligible loss of consistency. For this investigation, the slump test was adopted due to its convenience and simplicity as the workability evaluation for the fresh concrete for all the various mixes. Table 2 presents the findings of the slump test. Referring to Table 2, it is clear that potassium alum has the ability to absorb water more than portland limestone cement, causing a slight decrease in the slump of the concrete mix. As the percentage of potassium alum increases, the slum reduces as depicted in Table 2. These findings are similar to those of Rahel and Hiba (2016), which reported that by increasing the amount of alum sludge, the slump decrease became more pronounced. This reduction is a result of the high mixing water demand for potassium alum. As seen in Table 2, the slump level starts to drop from 74 mm to 15 mm at 20% potassium alum. The 2.5% addition of potassium alum provides the best workability.

Table 2. Variation of Slump with Increase in Alum Content

ALUM CONTENT (%)	**0**	**2.5**	**5**	**7.5**	**10**	**12.5**	**15**	**17.5**	**20**
SLUMP LEVEL (mm)	75	73	70	70	60	50	45	30	15

4. CONCLUSION

The effect of concentrated potassium alum water on the properties of concrete is investigated in this paper. Based on the findings, we concluded that;

- The 2.5% potassium alum concentrated water improved the compressive strength by 3%.
- Beyond 2.5% concentrated potassium alum water reduces compressive strength.

- An increase in potassium alum content results in a reduction in compressive strength and workability.
- Potassium alum absorbs water more than portland limestone cement.
- Reduction in workability is attributed to the high mixing water demand of potassium alum.

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