مجلة جامعة بني وليد للعلوم الإنسانية والتطبيقية

تصدر عن جامعة بني وليد – ليبيا

Website: https://jhas-bwu.com/index.php/bwjhas/index

المجلد التاسع، العدد الثالث الصفحات (603-613) 2024م

تحسين نفاذية الخرسانة باستخدام المضاف كريستال إكس

نوري سليمان عتيق [1] ، أشرف مفتاح ميلاد [2] ، عبدالحميد محمد مصباح [3]، دانييل كولو [4]

[3.2.1] قسم الهندسة المدنية، كلية الهندسة ،جامعة بني وليد ، بني وليد ، ليبيا .

[4] قسم الهندسة المدنية، الجامعة الفيدرالية للتقنية، مينا، نيجيريا.

Nori.ateig@bwu.edu.ly

Reducing Concrete's Permeability through the use of Crystal-X as an additive mixture

Nori.S.Ateig[1] , Ashraf M.L.Milad [2,*], Abdalhamid Mohammed musbah[3] and Daniel Kolo[4]

Department of Civil Engineering, College of Engineering, Bani Waleed University, Bani Walid, Libya.. [3.2.1]

Department of Civil Engineering, Federal University of Technology, Minna, Nigeria[4]

تاريخ الاستلام:02-08-2024 تاريخ القبول: 19-08-2024 تاريخ النشر : 04-09-2024

الملخص:

تشير نفاذية الخرسانة إلى قدرتها على السماح بمرور الماء والرطوبة. تلعب النفاذية دورًا حاسمًا في جوانب مختلفة، بما في ذلك الحفاظ على طول عمر الهياكل والمظهر الجمالي ، فضلاً عن ذلك تقليل المشاكل المتعلقة بالتسرب والتدهور. تم ابتكار العديد من الطرق لتعزيز نفاذية الخرسانة، وتتضمن إحدى هذه الطرق إضافة بلورات كيميائية تسمى **Crystal-X** ، تعمل هذه المواد على تحسين الخصائص الهيدروليكية للخرسانة ، مما يقلل من احتمالية تسرب المياه، تمتلك **Crystal-X** القدرة على امتصاص الماء الموجود داخل مسام الخرسانة وتحويله إلى بلورات غير قابلة للذوبان، عندما تصبح المسامات مشبعة بهذه البلورات، فإنها تخلق حاجزًا يمنع دخول الماء والرطوبة ، تم توضيح نتائج الاختبارات المعملية المتعددة التي أجريت على كل من الخرسانة الطازجة والمصلبة بعد دمجها **Crystal-X** كمادة مضافة، بجرعات تتراوح من 0.9٪ إلى 1.3٪ من وزن الإسمنت. تم تقييم قابلية الخرسانة للعمل من خلال اختبار الانكماش، في حين تم تقييم حالتها الصلبة من خلال اختبارات قياس قوة الضغط والنفاذية ومعدل الامتصاص، بعد فترة معالجة مدتها 28 يومًا، أدى إضافة **Crystal-X** بمعدل 1.3٪ من وزن الإسمنت إلى زيادة في قوة ضغط الخرسانة بنسبة 15.93٪. وبالمثل، انخفضت نفاذية الخرسانة بنسبة 11.9٪ عند إضافتها بنفس المعدل.

الكلمات الدالة: نفاذية الخرسانة، الإسمنت، خليط مضاف، **Crystal-X**.

Abstract

The permeability of concrete refers to its capacity to allow the passage of water and moisture. Permeability plays a crucial role in various aspects, including preserving the longevity and visual appeal of structures, as well as minimizing issues related to leakage and deterioration. Several methods have been devised to enhance the permeability of concrete, and one such method involves incorporating chemical crystals called Crystal-X. These materials improve the concrete's hydrophobic properties, reducing the likelihood of water leakage. Crystal-X possesses the capacity to absorb water that is found within the pores of the concrete and transform it into crystals that are not soluble. When the pores become saturated with these crystals, they create a barrier that prevents water and moisture from entering. The outcomes of multiple laboratory tests performed on both fresh and hardened concrete were elucidated and clarified subsequent to the incorporation of Crystal-X as an additive, at dosages ranging from 0.9% to 1.3% of the weight of the cement. The concrete's workability was assessed through a slump test, while its hardened state was evaluated through tests measuring compressive strength, permeability, and absorption rate. After a curing period of 28 days, the addition of Crystal-X at a rate of 1.3 % by weight of cement resulted in a 15.93% increase in the compressive strength of the concrete. Similarly, the permeability of the concrete decreased by 11.9% when Crystal-X was added at the same rate.

Keywords: Crystal-X, Concrete Permeability, Cement, Additive Mixture.

1. INTRODUCTION

Concrete is widely regarded as a highly significant construction material utilized in the realm of building and construction. It is distinguished by its exceptional ability to withstand compression, tension, and bending. Nevertheless, concrete is susceptible to degradation and corrosion due to the influence of diverse environmental elements such as precipitation, snowfall, and moisture. Permeability is a primary factor contributing to this problem.

In order to address the problem of permeability, different approaches have been investigated, such as employing supplementary cementitious materials, applying surface sealants, and utilizing chemical admixtures (De Souza Oliveira et al., 2021; Aslani et al., 2022). These admixtures generally consist of substances such as Portland cement, silica sand, and a variety of active components. Upon incorporation into the concrete mixture, these active constituents undergo a chemical reaction with water and calcium hydroxide, resulting in the formation of crystals that are insoluble. This phenomenon, referred to as "chemical reaction crystallization," persists gradually, even in the presence of moisture, guaranteeing long-lasting waterproofing (Al-Rashed, Radi, and Maher Jabari., 2020). Crystalline waterproofing additives have become notable for their capacity to internally obstruct the pores and capillaries in concrete, effectively halting the entry of water and moisture. Crystal-X is an additive that has demonstrated potential in improving the impermeability of concrete (Lohtia and Joshi, 1996).

Using Crystal-X waterproofing admixtures has multiple advantages, according to studies. The study conducted by Tibbetts et al. (2021) emphasizes the efficacy of permeability-reducing admixtures (PRA) in augmenting the durability of concrete. The study highlights the importance of PRAs in reducing water and ionic movement, which are major factors in the deterioration of concrete. These admixtures enhance the durability of the concrete by reducing its permeability, thereby safeguarding the reinforcing steel from corrosion and greatly extending the lifespan of the structure. The study conducted by Wang et al. (2024) highlights the significance of surface treatments in preventing corrosion of reinforcement materials. It emphasizes the crucial role of ensuring dry conditions within the concrete. Certain crystalline admixtures exhibit the ability to repair themselves. When fissures emerge, the inactive chemicals interact with moisture, generating fresh crystals that seal the fissures and hinder additional water penetration. (Huseien, et al., 2019; Nair, et al., 2022) examines the concept of self-healing concrete, emphasizing the potential of different technologies, such as crystalline admixtures, to improve the durability and lifespan of concrete.

Crystal-X waterproofing admixtures can be affected by various factors, such as: Optimal crystal formation and distribution within the concrete are dependent on precise dosage and thorough mixing (Jahandari et al., 2023). Effective curing is crucial for facilitating chemical reactions (Liang et al., 2024; Zhang et al., 2017). The performance of the admixture can be influenced by the water-to-cement ratio, type of aggregate, and other parameters in the concrete mix design.

The use of crystal-X waterproofing admixtures provides a solution that is both dependable and efficient in terms of lowering the permeability of concrete and increasing its durability (Azarsa et al,. 2019) Because of their capacity to react with water and to heal themselves, they are an excellent option for a wide range of applications, including water-retaining structures and basement walls with water retention capabilities. However, in order to achieve optimal performance, it is essential to have a proper understanding of their application, including their limitations and the potential interactions they may have with other concrete constituents.

The weight of the cementitious binding materials in this research was fixed at 375 kg/m^3. The characteristics of the concrete were assessed using various tests, including the slump test. The hardened state of concrete was chosen for permeability testing and underwent compressive strength testing at 7 and 28 days of age. In addition, the absorption rate was evaluated to ascertain the concrete's durability.

2. MATERIALS AND METHODS

2.1. The Raw Materials

Cement: The study utilized Ordinary Portland cement from the Zliten Cement Factory for the production of all concrete mixtures. **Table 1** displays the physical and mechanical characteristics of the cement. The results indicate that the cement meets the requirements set by the Libyan specifications (1997/340).

Table 1. Outline of the cement's characteristics

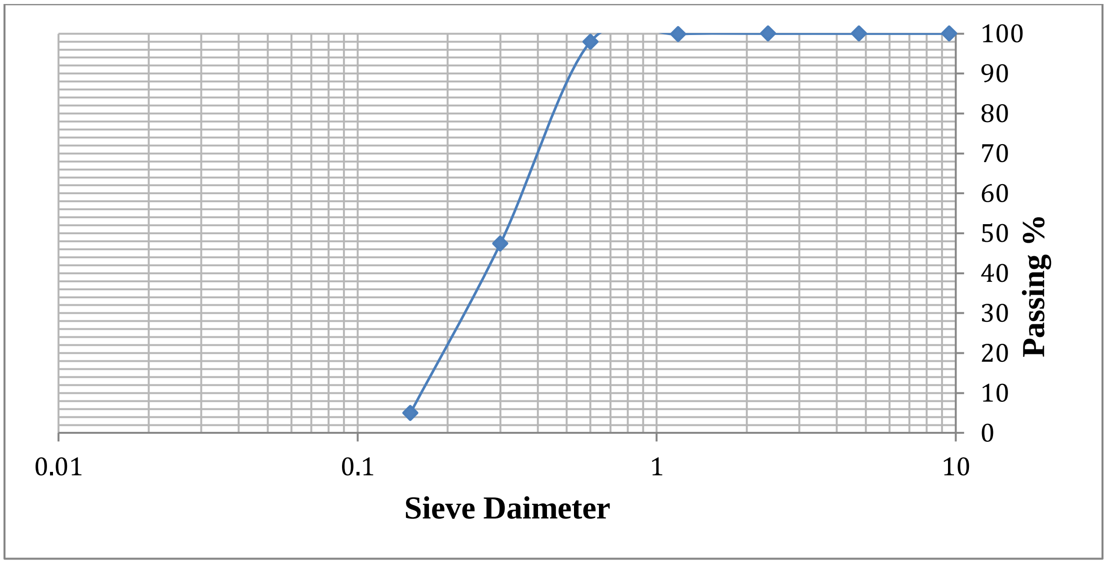
Properties	Value
Standard water ratio (%)	23
Initial Setting (min)	187
Final Sitting (hr)	4
Soundness (mm)	1
Fineness (g/cm^2)	2512
Compressive Strength at 3 days (N/mm^2)	28.9
Compressive Strength at 28 days (N/mm^2)	61

Aggregate: The mixture consisted of locally sourced fine aggregate and coarse aggregate in a volume ratio of 1:1.47. **Table 2** displays the attributes of aggregates. The sieve analysis of fine and coarse aggregates is depicted in **Figures 1** and **2**, respectively.

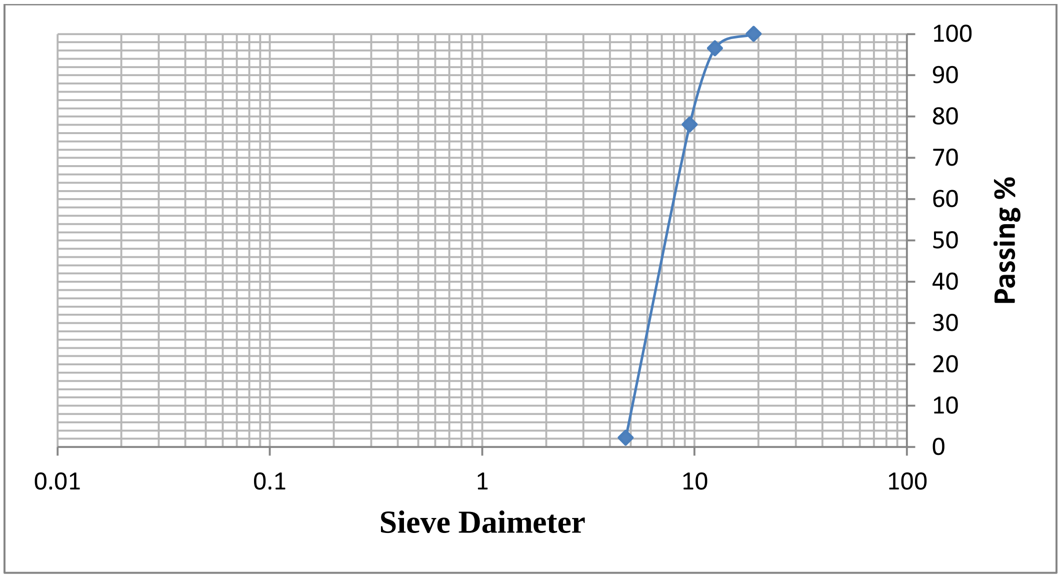
Table 2. Outline of the aggregate's characteristics

Properties	Fine aggregate	Coarse aggregate
Specific Gravity	2.69	2.76
Density (kg/m^3)	1530	1959.33
Absorption Ratio (%)	0.517	0.755
Impact Value (%)	-	19.93
Crushing Value (%)	-	12.46
Chloride content (%)	0.0092	0.0241
Sulphate content (%)	0.0033	0.0241

Percentage of salts (%)	–	0.6704
Fine Particles Retio (%)	1.72	–
Ratio of dissolved solids(%)	0.0258	–
pH	9.17	–



Figures 1: Fine Aggregate Particle Size Distribution (Sieve Analysis)



Figures 2: Coarse Aggregate Particle Size Distribution (Sieve Analysis)

Mixing Water: The water utilized in concrete mixtures is drinkable and devoid of organic substances and contaminants. Multiple sources indicate that water is typically considered suitable when the total dissolved salts in it are below 2000 parts per million (Gokulanathan, et al.,2021; Nikookar, et al., 2023). Furthermore, the utilization of water containing a certain salinity percentage does not seem to have a detrimental impact on the long-term robustness or durability of concrete (Al-Jabri *et al.*, 2011). However, it does result in blemishes and imperfections on the concrete surface, as well as heightens the likelihood of corrosion occurring on the reinforcing steel. Hence, it is advisable to avoid incorporating water with a salinity percentage into the mixture of reinforced concrete (Zhao, et al., 2021; Mangi, et al., 2021)

Crystalline additive: Crystalline is a chemical additive included into concrete mixture during its production to enhance its resistance to water and decrease its permeability. This chemical undergoes a reaction with water to generate small crystals within the concrete. Once these crystals attain a specific size, they consist of this quantity of crystal cells. Consequently, the permeability of the concrete is decreased, so enhancing its strength and long-term durability (Nasim, et al., (2020); Ravitheja, et al (2019)). At addition rates ranging from 0.8 to 1% of the weight of the cement used, Crystal – X was directly added to the concrete in the mixer and poured with water.

3. RESULT AND DISCUSSIONS

3.1. Concrete Slump Test

Slump test was conducted on the fresh concrete, it is a means of assessing the consistency of fresh concrete. A steel cylindrical cone was used. It was placed on a solid impermeable flat base then filled with fresh concrete in three layers. Each layer is tampered 25 times to ensure compaction. The slump may take one of three possible forms namely: true slump, shear slump and collapse slump. A true slump is generally desired: the concrete subsides a little when the cone is removed, keeping more to the initial shape. For a shear slump, the top of the concrete shears off and slips sideways and for a collapse slump, the concrete collapses completely. **Plate 1** presents the slump test being conducted on the three different samples. Results of the slump test are presented on Figure 3.

Plate 1: Slump test in progress

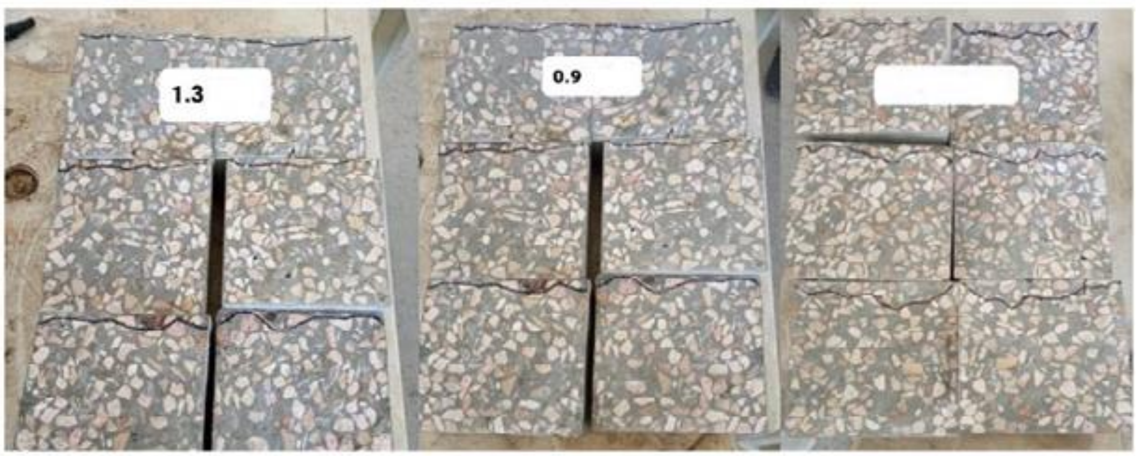


Plate 2: Samples after Water absorption test

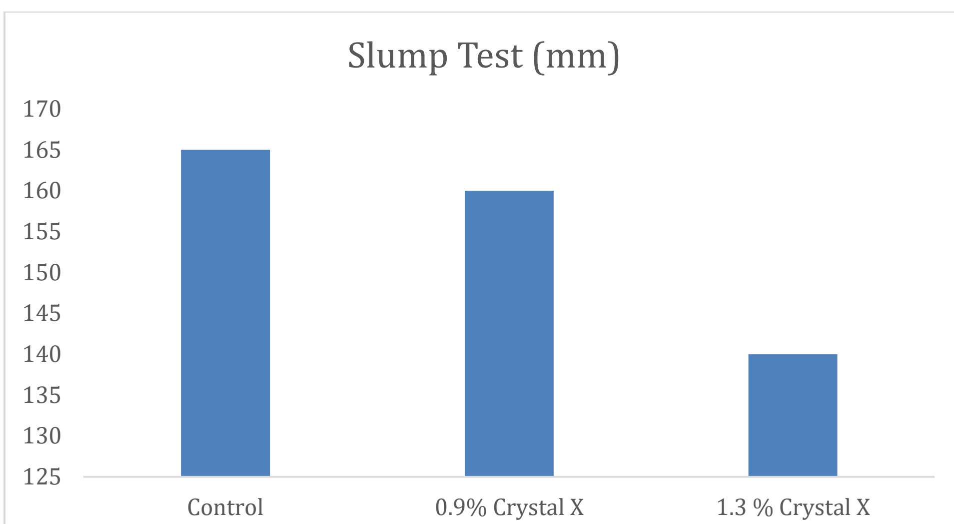


Figure 3: Slump test result

3.2. Concrete Compressive Strength Test

The 7 and 28 days compressive strength results for the three samples (Control, 0.9% and 1.3% Crystal–X) are presented on **Tables 3** and **4** respectively. As can be seen from Table 3, a general increase in the compressive strength of concrete was observed with an increase in Crystal–X content. The highest 7 day compressive strength of 32.23 MPa was obtained at 1.3% Crystal–X content. The same trend was exhibited for the 28 days compressive strength as an increase in Crystal–X content returned higher compressive strength values. The highest 28 days strength was recorded at 1.3% Crystal–X content with a value of 43.30 MPa.

Table 3: 7days compressive strength

Mix Type	Trial 1	Trial 2	Trial 3	Average Compressive Strength (Mpa)
Control	25.70	26.40	29.30	27.13
0.9% Crystal X	27.00	29.00	31.60	29.20
1.3 % Crystal X	32.80	28.10	32.80	32.23

Table 4: 28days compressive strength

Mix Type	Trial 1	Trial 2	Trial 3	Average Compressive Strength (Mpa)
Control	40.10	36.30	32.90	36.40
0.9% Crystal X	39.90	42.80	44.70	42.40
1.3 % Crystal X	41.40	43.40	45.10	43.30

3.3. Concrete Permeability

Concrete permeability test result for the three mix types (Control, 0.9 and 1.3% Crystal–X) is presented on **Table 5**. Permeability of the concrete samples decreased with an increase in Crystal–X content.

Table 5: Concrete Permeability test

Mix Type	Trial 1	Trial 2	Trial 3	Average Permeability (cm)
Control	2.40	2.00	2.10	2.16
0.9% Crystal X	1.12	1.30	1.90	1.44
1.3 % Crystal X	1.17	1.00	1.30	1.33

3.4. Water Absorption

The 24-hour water absorption test result for concrete produced with the three mix types is presented on **Table 6.** A general decrease in absorption rate was recorded with an increase in Crystal-X content.

Table 6: Absorption rate

Mix Type	**Cube Weight (Kg)**	**Cube Weight (Kg)**	**Absorption Rate (%)**
Control	7.79	7.86	0.83
0.9% Crystal X	7.70	7.74	0.45
1.3 % Crystal X	7.84	7.86	0.25

4. Conclusion

Based on the results from this research, the following conclusion is drawn:

- The physical properties test conducted on the constituent materials showed the have satisfactory properties and can be used for concrete production. A general increase in the compressive strength of concrete with an increase in Crystal-X dosage at 7 and 28 days. The highest compressive strength value of 43.30 MPa was recorded at 1.3% Crystal-X dosage, representing a 15.93% increase in compressive strength. The addition of Crystal-X resulted in a general decrease in the concrete permeability.

- addition Crystal X at 0.9% and 1.3% of the cement weight in concrete, respectively, resulting in a 33.3% and 38.4% decrease in permeability compared to the reference mix. This indicates the efficacy of Crystal X in improving the permeabilization of concrete. These findings indicate that Crystal X has the potential to enhance the longevity and resilience of concrete against water penetration and other environmental influences.

- Concurrently with an increase in the additive dosage in the concrete mix, a reduction in slump value was noted. These findings indicate that when the proportion of the additive rises, the workability of the concrete declines, potentially impacting the ease of placing and compacting the concrete during construction.

References

Al-Jabri, K. S., Al-Saidy, A. H., Taha, R., & Al-Kemyani, A. J. (2011). Effect of using wastewater on the properties of high strength concrete. Procedia Engineering, 14, 370-376. https://doi.org/10.1016/j.proeng.2011.07.046

Al-Rashed, R., & Jabari, M. (2020). Dual-crystallization waterproofing technology for topical treatment of concrete. Case Studies in Construction Materials, 13, e00408. https://doi.org/10.1016/j.cscm.2020.e00408

Aslani, F., Zhang, Y., Manning, D., Valdez, L. C., & Manning, N. (2022). Additive and alternative materials to cement for well plugging and abandonment: A state-of-the-art review. Journal of Petroleum Science and Engineering, 215, 110728. https://doi.org/10.1016/j.petrol.2022.110728

Azarsa, P., Gupta, R., & Biparva, A. (2019). Assessment of self-healing and durability parameters of concretes incorporating crystalline admixtures and Portland Limestone Cement. Cement and Concrete Composites, 99, 17-31. https://doi.org/10.1016/j.cemconcomp.2019.02.017

de Souza Oliveira, A., Gomes, O. D. F. M., Ferrara, L., Fairbairn, E. D. M. R., & Toledo Filho, R. D. (2021). An overview of a twofold effect of crystalline admixtures in cement-based materials: from permeability-reducers to self-healing stimulators. Journal of Building Engineering, 41, 102400. https://doi.org/10.1016/j.jobe.2021.102400

Gokulanathan, V., Arun, K., & Priyadharshini, P. (2021). Fresh and hardened properties of five non-potable water mixed and cured concrete: A comprehensive review. Construction and Building Materials, 309, 125089. https://doi.org/10.1016/j.conbuildmat.2021.125089

Huseien, G. F., Shah, K. W., & Sam, A. R. M. (2019). Sustainability of nanomaterials based self-healing concrete: An all-inclusive insight. Journal of Building Engineering, 23, 155-171. https://doi.org/10.1016/j.jobe.2019.01.032

Jahandari, S., Tao, Z., Alim, M. A., & Li, W. (2023). Integral waterproof concrete: A comprehensive review. Journal of Building Engineering, 107718. https://doi.org/10.1016/j.jobe.2023.107718

Liang, C., Li, B., Guo, M. Z., Hou, S., Wang, S., Gao, Y., & Wang, X. (2024). Effects of early-age carbonation curing on the properties of cement-based materials: A review. Journal of Building Engineering, 108495. https://doi.org/10.1016/j.jobe.2024.108495

Lohtia, R. P., & Joshi, R. C. (1996). Mineral admixtures. In Concrete admixtures handbook (pp. 657-739). William Andrew Publishing. https://doi.org/10.1016/B978-081551373-5.50014-3

Mangi, S. A., Makhija, A., Raza, M. S., Khahro, S. H., & Jhatial, A. A. (2021). A comprehensive review on effects of seawater on engineering properties of concrete. Silicon, 1-8. https://doi.org/10.1007/s12633-020-00724-7

Nair, P. S., Gupta, R., & Agrawal, V. (2022). Self-healing concrete: a promising innovation for sustainability-a review. Materials Today: Proceedings, 65, 1410-1417. https://doi.org/10.1016/j.matpr.2022.04.393

Nasim, M., Dewangan, U. K., & Deo, S. V. (2020). Autonomous healing in concrete by crystalline admixture: A review. Materials Today: Proceedings, 32, 638-644. https://doi.org/10.1016/j.matpr.2020.03.116

Nikookar, M., Brake, N. A., Adesina, M., Rahman, A., & Selvaratnam, T. (2023). Past, current, and future re-use of recycled non-potable water sources in concrete applications to reduce freshwater consumption-A Review. Cleaner Materials, 100203. https://doi.org/10.1016/j.clema.2023.100203

Ravitheja, A., Reddy, T. C. S., & Sashidhar, C. (2019). Self-healing concrete with crystalline admixture-a review. Journal of Wuhan University of Technology-Mater. Sci. Ed., 34, 1143-1154. https://doi.org/10.1007/s11595-019-2171-2

Tibbetts, C. M., Riding, K. A., & Ferraro, C. C. (2021). A critical review of the testing and benefits of permeability-reducing admixtures for use in concrete. Cement, 6, 100016. https://doi.org/10.1016/j.cement.2021.100016

Wang, Q., Zhou, X., Sun, X., Aslam, R., Wang, R., Sun, Y., ... & Li, X. (2024). Corrosion of Reinforcement in Reinforced Concrete: Influencing Factors, Detection Methods, and Control Techniques-A Review. Journal of Testing and Evaluation, 52(5), 3096-3122. https://doi.org/10.1520/JTE20230752

Zhang, D., Ghouleh, Z., & Shao, Y. (2017). Review on carbonation curing of cement-based materials. Journal of CO2 Utilization, 21, 119-131. https://doi.org/10.1016/j.jcou.2017.07.003

Zhao, Y., Hu, X., Shi, C., Zhang, Z., & Zhu, D. (2021). A review on seawater sea-sand concrete: Mixture proportion, hydration, microstructure and properties. Construction and Building Materials, 295, 123602. https://doi.org/10.1016/j.conbuildmat.2021.123602