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Assessing the Impact of Composite Salt-Contaminated Groundwater on compressive strength of Concrete Foundations: A Case Study in Basra, Iraq

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ABSTRACT

This study aims to investigate the impact of groundwater containing composite salts on the compressive strength of concrete foundations located in the city of Basra in Iraq. The groundwater in this city demonstrates high concentrations of salts, particularly significant amounts of magnesium, sodium, and calcium salts, which are present in close proximity to the soil surface. To accomplish this objective, a foundation in the mentioned city was selected, which has been constructed since 2012 and remains incomplete to this day. The chosen foundation covers an area of approximately 2000 m^2. Samples were collected from seven distinct regions, with three samples obtained from each region, resulting in a total of 21 samples. The selected regions were those most affected by groundwater, specifically those closest to the soil, such as regions near edges or openings within the foundation. The results of compressive strength tests conducted on all specimens indicated a remarkable decline in compressive strength. On average, the findings revealed a 30% reduction in compressive strength, highlighting the significant impact of composite salt-contaminated groundwater on the durability of concrete foundations.

Keywords:

Salt-contaminated groundwater; Concrete foundation; Compressive strength; Magnesium salts; Sodium and Calcium salts.

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1. INTRODUCTION

Concrete is one of the most widely used construction materials in the world. Its compressive strength is a crucial factor that determines its performance and durability. Compressive strength, can be improved in a number of ways. Some of these methods include: using cementitious materials such as fly ash and ground granulated blast furnace slag [1], adding fibers such as steel fibers [2, 3], polypropylene and carbon fibers [4, 5], etc. Since these additives can enhance microstructural properties of the concrete matrix and the status of its voids and pores. For example, Alapour et al. [6] studied the effects of slag cement on the sulfate resistance of concrete cylinders after 38 years of exposure to sodium sulfate solutions. Their results showed that a 65% slag substitution of portland cement was very effective in improving the performance of concrete exposed to sodium sulfate.

In this context, the environment plays a critical role in determining the service life of concrete structures, especially in regions with severe climate conditions. If these factors are not properly considered, they can severely compromise the durability of the structure [7, 8]. For instance, in marine environments, steel-reinforced concrete structures deteriorate due to the penetration of various chemical substances, including water [9], carbon dioxide [10], sulfates [11], and chlorides [12]. The presence of chloride ions is widely accepted to be the primary cause of steel corrosion in concrete structures in coastal regions [13]. This is because chloride ions can penetrate the concrete and react with the steel, forming a corrosive environment. The corrosion of steel can lead to a significant amount of early structural failures, with serious economic consequences.

Fundamentally, one of the most severe problems affecting concrete is sulphate attack [14]. Sulphates are naturally occurring chemicals that can be found in soil and groundwater. When sulphates come into contact with concrete, they can react with the cement in the concrete, which can lead to the formation of expansive products. These expansive products can cause the concrete to crack and spall [15-18]. These characteristics are accompanied by volume expansion and mass loss, which can lead to structural failure [19]. Many studies have investigated the compressive strength deterioration of concrete in a sulfate environment. These studies have considered a variety of variables, including the water-to-cement ratio [20], additives [21], sulfate concentration [22], dry-wet cycles [23], and erosion age [24].

Sulphate sources may manifest from either internal or external origins. While less prevalent, internal sources stem from materials employed in concrete production, such as hydraulic cement, fly ash, aggregate, and admixtures. Conversely, external sources are more common and usually crop up in soils and groundwater with high-sulphate levels, as well as due to atmospheric or industrial pollution [19]. There are several types of sulfate solutions that can cause this kind of damage, including magnesium, sodium, and calcium sulfate. Research has also revealed that the presence of certain minerals and compounds in the aggregate used in concrete can exacerbate the effects of sulfate attack [25, 26]. For example, the use of aggregates containing high levels of reactive silica can increase the potential for damage due to sulfate attack [25]. To mitigate the effects of sulfate attack, various methods have been proposed, including the use of sulfate-resistant cement, the addition of pozzolanic materials such as fly ash, nano and/or micro-silica, and the use of protective coatings [27, 28]. However, the effectiveness of these methods may vary depending on the specific conditions and the severity of the sulfate attack [29]. Wang et al. [30] found that concrete made with waste fly ash and coal gangue is feasible for use in coal mining subsidence areas with high groundwater levels. Tang et al. [31] showed that coal gangue can be used to replace cement in sustainable concrete, which improves the concrete's sulfate resistance.

This study aims to investigate the effects of composite salts such as magnesium, sodium, and calcium, on the compressive strength of concrete foundations. To assess the compressive strength, a total of 21 samples were extracted from a foundation that has been cast since 2012 and exposed to high levels of composite salt-contaminated groundwater that exist near the soil surface. The chosen foundation covers an area of approximately 2000 m^2. Samples were collected from seven distinct regions, with three samples obtained from each region, specifically from regions near edges or openings within the foundation.

2. EXPERIMENTAL PROGRAM

2.1. Case study description

The comprehensive depiction of the underground water level throughout the entire nation of Iraq can be observed through the map provided below (see Fig. 1). Additionally, Table 1, showcasing the depths of underground water in some regions of the studied Basra province, also accompanies this information. According to the values presented in Table 1, it becomes evident that the groundwater level is exceptionally elevated, with measurements reaching approximately 2 m below ground surface in certain areas.

Table 1: Depth of groundwater in some regions of the Basra province.

Region	Basra city	Al-Deir	Al-Shafi	Al-Sharsh	Basra airport
Depth [m]	2.3-7	2-5.5	2.5-7	2.7-8	3.5-9

2.2. Chemical properties of soil

A chemical analysis was conducted on the soil in some areas of Basra province and its findings have been documented in Table 2. The results indicate a significant presence of sulfate salts, specifically magnesium, sodium, and calcium salts, within the soil where the highest salts are respectively sodium, magnesium and calcium.

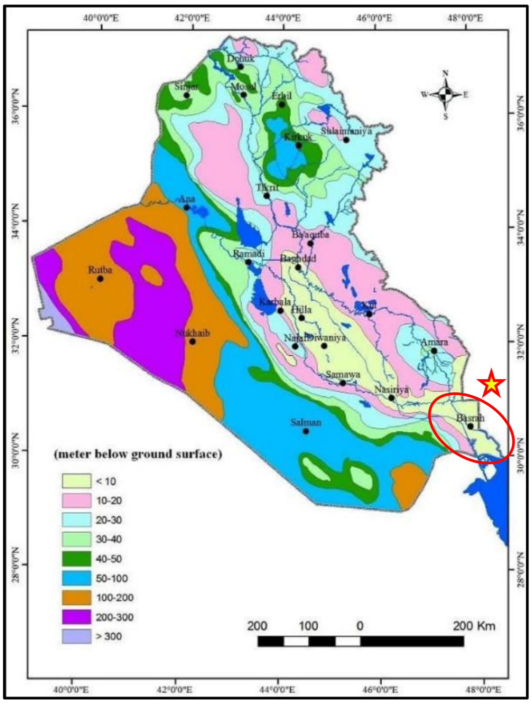

Fig.1 Depth of groundwater in hydrological zones.

Table 2: Chemical properties of the soil in Basra city.

Region	Depth	Ca^{+2}	Mg^{+2}	CL^{-1}	HCO^{-3}	$SO4^{-1}$	K^{+1}	Na^{+2}
	[cm]	[mmol/ L]						
Basra city	0-30	17.5	93.5	675	16	30.47	0.87	245.65
	30-86	11	42	190	17	24.46	1.71	65.22
	86-136	10	89.6	255	18	24.82	1.67	43.48
	+136	11	37	230	16	32.02	0.78	87.5

2.3. Materials

The type of cement used was salt-resistant Portland cement. It was produced at the Karbala Cement Factory and met the requirements outlined in the Iraqi Standard Specification No. 5 of 1984. It is worth mentioning that this standard was updated in 2019. The cement had a specific area of 3000 cm^2/g and a specific gravity of 3.15. The cement content of the concrete was 380 kg/m^3. Table 3 shows its chemical composition.

Table 3: Chemical composition of cement used in the study [%].

Material	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	SO_3	Insol	L.O.I	L.S.F
Cement	21.52	3.82	4.30	62.8	1.95	2.31	0.78	1.65	0.84

The fine aggregate utilized in the concrete mixes was sourced from the Al-Ukhaidir zone. In accordance with Iraqi Standard Specifications No. 45 of 1984, Table 4 outlines the properties of the utilized fine aggregate. The coarse aggregate utilized in all mixtures was obtained from Al-Nabai area in the form of rounded gravel. The maximum permitted size of the gravel, as per Iraqi Standard No. 45 of 1984, was 20 mm. Table 4 presents properties of the coarse aggregate used in the mixtures.

Table 4: The characteristics of coarse and fine aggregates.

Properties of aggregates	Coarse aggregate	Fine aggregate
Relative density [Dry]	2.66	2.61
Absorption [% of dry mass]	0.50	1.20
Salt percentage; SO_3 [%]	0.06	0.27
Maximum diameter [mm]	20	4.75

2.4. Extraction of core samples

To assess the compressive strength of the foundations, a total of 21 samples were extracted from seven distinct locations where they have been cast and surrounded by soil since 2012. The reason for choosing this foundation is that this foundation is submerged in groundwater with high salinity. It has been left unfinished since 10 years to this day, and no construction has been done on it. Three foundation samples were obtained from each of the seven regions. The chosen regions are those that have been significantly impacted by groundwater. The selection was based on the proximity of these regions to the soil. As a result, regions located near edges or openings within the foundation were specifically chosen for investigation. These specimens were extracted using a core drilling machine. For example, the first region where the first group of specimens were extracted, can be seen in the Fig.2.

(a)

(b)

(c)

Fig.2 Sampling technique a. prepare the sampling location, b. extraction core sample, c. core sample

2.5. Preparation of samples and compressive strength

After extracting the samples, the surface of the samples has been smoothed to perform the test where the grout was used for this aim (see Fig.3). As mentioned before, to evaluate the compressive strength based on BS 1881 [32] guidelines, 100×200 mm specimens were used. Each region was represented by three cylinders. After processing the surface of samples (see Fig. 4), they were tested for the evaluation of their compressive strength based on BS 1881 guidelines [32] in which an apparatus was employed to subject the samples to controlled levels of pressure.

(a)

(b)

Fig.3 Preparation specimens a. core sample, b. flattening of the sample surface

Fig.4 Test specimens after processing

3. TEST RESULTS AND DISCUSSION

This section provides a comprehensive analysis and discussion of the compressive strength test results obtained from the concrete foundation samples. First of all, salt crystallization on concrete surface should be discussed through visual observation. Fig. 5 shows the characteristic of salt crystallization on the concrete surface attacked by composite salt-contaminated groundwater. As can be clearly seen, the concrete surface is heavily affected by salt crystallization, with an abundance of salt crystals visible throughout. The salt crystallization extends from the base level to the surface of the foundation, indicating that the entire surface exposed to the salt-contaminated groundwater is covered in salt crystals. Furthermore, there is a varying degree of salt crystallization, likely resulting from the differential effects of capillary action and evaporation. As the sulfate solution moves through the concrete surface via capillary action, it undergoes evaporation and concentration, leading to the formation of salt crystals with different levels of gradation. Additionally, signs of erosion, cracks and splitting can be observed in the concrete (see Fig.5).

(a)

(b)

Fig.5 Foundation affected by composite salt-contaminated groundwater

3.1. Compressive strength

Table 5 shows the results of compressive strength tests in MPa and its reduction values for concrete foundation samples. The average results of three samples for each region are presented in Table 5, which showed a relatively high compressive strength of reference samples completely immersed in plain water free of sulfur. Figure 6 exhibits the meticulous and systematic procedure of conducting sample tests through the utilization of a sophisticated pressure apparatus. In the absence of exposure to salts, a compressive strength of 30.87 MPa was recorded for the reference sample which was taken from the concrete foundations during casting and cured in ordinary water for 28 days. This particular outcome served as a benchmark and was denoted by the symbol C as shown in Fig. 7. As mentioned above, the reduction rate of compressive strength is presented in Table 5. The reduction in compressive strength can be ascribed to various factors, including the existence of a substantial number of random micro cracks. These cracks facilitate the infiltration of both composite salt-contaminated groundwater and other substances into the concrete when these minerals penetrate and occupy the open spaces within the concrete's microstructure, it facilitates oxidation and leads to sulfate attack in these particular areas, leading to a significant decline in compressive strength [27, 33]. Furthermore, the voids that are filled with minerals within the coarse aggregate often experience cracking [34]. These cracks exhibit either radial orientations or propagate into the cement matrix. Additionally, the expansion caused by crystal growth and absorption of these minerals generates pressure, potentially contributing to the observed cracking [35, 36]. Moreover, the deposits within the voids can diminish their effectiveness in preventing water penetration when the concrete foundation is exposed to groundwater [34, 37]. Liu et al. [24, 38] conducted a series of micro tests, including X-ray diffraction (XRD), scanning electron microscopy (SEM), Fourier transform infrared spectroscopy (FTIR), and thermogravimetric (TG) analysis, to understand the deterioration mechanism of sulfate-attacked concrete. They found that the main sulfate products are gypsum and ettringite. They reported that the performance and microproducts of concrete were significantly affected by the sulfate-rich environment.

Fig. 6 Sample testing to determine the compressive strength

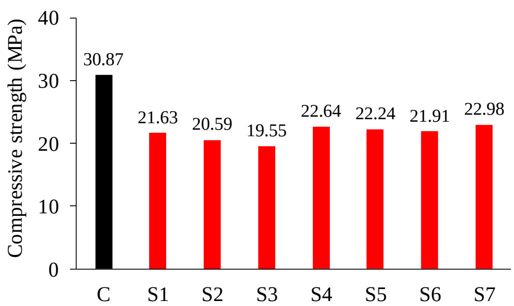

Fig.7 The compressive strength of the specimens.

Table 5: Compressive strength of the concrete foundations.

Region	ID	Compressive strength [MPa]	Diff.
-	C	30.87	1.00
I	S1	21.63	0.70
II	S2	20.59	0.67
III	S3	19.55	0.63
IV	S4	22.64	0.73
V	S5	22.24	0.72
VI	S6	21.91	0.71
VII	S7	22.98	0.74

As mentioned above, based on Table 5, it is observed that compressive strength decreased significantly in foundation samples that were subjected to composite salts of varying concentrations. For example, the compressive strength of the S3 foundation sample decreased by approximately 37% over a period of 10 years. This decline can be attributed to the elevated levels of salts present in the groundwater. Specifically, the salts of magnesium, sodium, and calcium have been identified as contributing factors. When compared to the reference counterpart, this decrease in strength highlights the impact of environmental factors on the long-term durability of concrete structures. In other words, this decrease did not exceed 11.32 MPa in any selected region during the 10-year period. The compressive strength of the specimens is illustrated in Fig. 7. Based on the compressive strength tests performed on all samples, the results showed a significant reduction in compressive strength. On average, the findings revealed a 30% reduction in compressive strength. This result is consistent with the findings of previous studies. Zhao et al. [39] reported a reduction in the mass of concrete by approximately 10% after it was immersed in a 5% sulfate solution for a period of 9 months. According to the findings after 2 and 4 months by Liu et al. [24], it has been observed that the compressive strength of the concrete decreases as the concentration of sulfate solution increases.

4. CONCLUSION

In conclusion, sulfate attack can have a significant impact on the compressive strength and overall durability of concrete. It is important to carefully consider the type and concentration of sulfate ions present in the environment, as well as the properties of the aggregates and other materials used in concrete construction. By taking appropriate measures to prevent or mitigate sulfate attack, the longevity and performance of concrete structures can be improved. The present paper offers an extensive investigation into this degrading agent, encompassing its causes and effects, with attention given to south Iraq and a special focus on Basra City in Iraq. The research results are summarized below.

- The phenomenon known as sulphate attack is a prevalent mechanism that causes degradation in structures. This form of chemical damage can lead to the development of cracks, spalling, and disintegration of the structure, ultimately resulting in a decrease in its strength.
- Based on the compressive strength tests performed on all samples, the results showed a significant reduction in compressive strength. On average, the findings revealed a 30% reduction in compressive strength.
- The study's outcomes have demonstrated that sulphate attack, with its various mechanisms, has adverse impacts on structures. Despite the wide distribution of groundwater salts within the south Iraq region, the successful implementation of precautionary measures can effectively limit their impact on structures.
- The recommendation is, therefore, that supplementary materials such as micro-silica, fly ash, and blast furnace slag can be used as inexpensive materials with a strong effect on the properties of concrete in the concrete mix and its sulfate resistance; as a result, the deterioration in compressive strength could be decresed and the strength for the production of the high performance concrete could be increased.

REFERENCES

[1] J. Ahmad *et al.*, "A comprehensive review on the ground granulated blast furnace slag (GGBS) in concrete production," *Sustainability,* vol. 14, no. 14, p. 8783, 2022, doi: doi.org/10.3390/su14148783

[2] N. SI Al Saffar, "Mechanical properties of steel fibrous concrete," *Al-Rafidain Engineering Journal (AREJ),* vol. 14, no. 3, pp. 43-57, 2006, doi: 10.33899/RENGJ.2006.45308

[3] P. Zhang, C. Wang, Z. Gao, and F. Wang, "A review on fracture properties of steel fiber reinforced concrete," *Journal of Building Engineering,* p. 105975, 2023.

[4] S. Sami Majeed, "Modulus of Rupture of Fully and Partially Reinforced Concrete Beams With Polypropylene Fibers," *Al-Rafidain Engineering Journal (AREJ),* vol. 21, no. 2, pp. 40-51, 2013, doi: 10.33899/rengj.2013.72714

[5] I. A. Aziz and K. I. Mohammed, "State-of-the-art for Strengthening and Rehabilitating Structural Beams Using Carbon Fiber Reinforced Polymers Configurations (A Review)," *Al-Rafidain Engineering Journal (AREJ),* vol. 27, no. 2, pp. 49-59, 2022, doi: 10.33899/rengj.2022.133019.1162

[6] F. Alapour and R. D. Hooton, "Sulfate Resistance of Portland and Slag Cement Concretes Exposed to Sodium Sulfate for 38 Years," *ACI Materials Journal*, vol. 114, no. 3, 2017, doi: 10.14359/51689678

[7] A. Al-Gahtani and M. Maslehuddin, "Characteristics of the Arabian Gulf environment and its impact on concrete durability–an overview," in *The 6th Saudi Engineering Conference, KFUPM, Dhahran, December 2002*, 2002.

[8] N. H. Al_jubory, T. W. Ahmed, and R. S. Zidan, "A Review on Mix Design of Self-Compacting Concrete," *Al-Rafidain Engineering Journal (AREJ),* vol. 25, no. 2, pp. 12-21, 2020, doi: doi.org/10.1016/j.conbuildmat.2015.03.079

[9] J. Liu, F. Xing, B. Dong, H. Ma, and D. Pan, "Study on surface permeability of concrete under immersion," *Materials,* vol. 7, no. 2, pp. 876-886, 2014, doi: doi.org/10.3390/ma7020876

[10] Q. Qiu, Z. Gu, J. Xiang, C. Huang, and B. Dong, "Carbonation Study of Cement-Based Material by Electrochemical Impedance Method," *ACI Materials journal*, vol. 114, no. 4, 2017, doi: 10.14359/51689778

[11] S. W. Tang, Y. Yao, C. Andrade, and Z. Li, "Recent durability studies on concrete structure," *Cement and Concrete Research,* vol. 78, pp. 143-154, 2015, doi: doi.org/10.1016/j.cemconres.2015.05.021

[12] J. Liu *et al.*, "Understanding the interacted mechanism between carbonation and chloride aerosol attack in ordinary Portland cement concrete," *Cement and Concrete Research,* vol. 95, pp. 217-225, 2017, doi: doi.org/10.1016/j.cemconres.2017.02.032

[13] M. H. Tadayon, M. Shekarchi, and M. Tadayon, "Long-term field study of chloride ingress in concretes containing pozzolans exposed to severe marine tidal zone," *Construction and Building Materials,* vol. 123, pp. 611-616, 2016, doi: doi.org/10.1016/j.conbuildmat.2016.07.074

[14] M. Elsayed, B. A. Tayeh, Y. Taha, and A. Abd El-Azim, "Experimental investigation on the behaviour of crumb rubber concrete columns exposed to chloride–sulphate attack," in *Structures*, 2022, vol. 46: Elsevier, pp. 246-264, doi: doi.org/10.1016/j.jobe.2023.105975

[15] M. Almohammad-albakkar, K. Behfarnia, and H. Mousavi, "Estimation of drying shrinkage in self-compacting concrete containing micro- and nano-silica using appropriate models," *Innovative Infrastructure Solutions,* vol. 7, no. 5, p. 324, 2022/09/07 2022, doi: 10.1007/s41062-022-00914-9.

[16] A. M. Diab, H. E. Elyamany, M. Abd Elmoaty, and A. H. Shalan, "Prediction of concrete compressive strength due to long term sulfate attack using neural network," *Alexandria Engineering Journal*, vol. 53, no. 3, pp. 627-642, 2014, doi: doi.org/10.1016/j.aej.2014.04.002

[17] M. Almohammad-albakkar and K. Behfarnia, "Effects of the combined usage of micro and nano-silica on the drying shrinkage and compressive strength of the self-compacting concrete," *Journal of Sustainable Cement-Based Materials,* vol. 10, no. 2, pp. 92-110, 2021, doi: doi.org/10.1080/21650373.2020.1755382

[18] F. Findik and F. Findik, "Civil engineering materials," *Heritage and Sustainable Development,* vol. 3, no. 2, p. 154, 2021, doi: https://doi.org/10.1016/C2014-0-03170-X

[19] G. Zhao, J. Li, M. Shi, H. Fan, J. Cui, and F. Xie, "Degradation mechanisms of cast-in-situ concrete subjected to internal-external combined sulfate attack," *Construction and Building Materials,* vol. 248, p. 118683, 2020, doi: doi.org/10.1016/j.conbuildmat.2020.118683

[20] H. Cheng, T. Liu, D. Zou, and A. Zhou, "Compressive strength assessment of sulfate-attacked concrete by using sulfate ions distributions," *Construction and Building Materials,* vol. 293, p. 123550, 2021, doi: doi.org/10.1016/j.conbuildmat.2021.123550

[21] H. Zeng, Y. Li, J. Zhang, P. Chong, and K. Zhang, "Effect of limestone powder and fly ash on the pH evolution coefficient of concrete in a sulfate-freeze–thaw environment," *Journal of Materials Research and Technology,* vol. 16, pp. 1889-1903, 2022, doi: doi.org/10.1016/j.jmrt.2021.12.033

[22] D. Zou, S. Qin, T. Liu, and A. Jivkov, "Experimental and numerical study of the effects of solution concentration and temperature on concrete under external sulfate attack," *Cement and Concrete Research,* vol. 139, p. 106284, 2021, doi: doi.org/10.1016/j.cemconres.2020.106284

[23] F. Liu, T. Zhang, T. Luo, M. Zhou, K. Zhang, and W. Ma, "Study on the Deterioration of Concrete under Dry–Wet Cycle and Sulfate Attack," *Materials,* vol. 13, no. 18, p. 4095, 2020, doi: doi.org/10.3390/ma13184095

[24] P. Liu, Y. Chen, W. Wang, and Z. Yu, "Effect of physical and chemical sulfate

attack on performance degradation of concrete under different conditions," *Chemical physics letters,* vol. 745, p. 137254, 2020, doi: doi.org/10.1016/j.cplett.2020.137254

[25] J. Bai, "Durability of sustainable construction materials," in *Sustainability of Construction Materials*: Elsevier, 2016, pp. 397-414, doi: doi.org/10.1016/B978-0-08-100370-1.00016-0

[26] D. B. Al-Haddad, G. A. Jokhio, and A. A. Tair, "Overview of Concrete Deterioration Due to Sulphate Attack and Comparison of Its Requirements in International Codes," in *BUiD Doctoral Research Conference 2022*, 2023, p. 199.

[27] M. Almohammad-albakkar and K. Behfarnia, "Water penetration resistance of the self-compacting concrete by the combined addition of micro and nano-silica," *Asian Journal of Civil Engineering,* vol. 22, no. 1, pp. 1-12, 2021, doi: 10.1007/s42107-020-00293-5

[28] H. Emamjomeha, K. Behfarniab, A. Rajic, and M. Almohammad-albakkar, "Influence of PVA and PP fibers addition on the durability and mechanical properties of engineered cementitious composites blended with silica fume and zeolite," *Research on Engineering Structures and Materials,* vol. 9, no. 2, pp. 457-473, 2023, doi: 10.17515/resm2022.491me0804

[29] A. Neville, "The confused world of sulfate attack on concrete," *Cement and Concrete research,* vol. 34, no. 8, pp. 1275-1296, 2004, doi: doi.org/10.1016/j.cemconres.2004.04.004

[30] J. Wang, Q. Qin, S. Hu, and K. Wu, "A concrete material with waste coal gangue and fly ash used for farmland drainage in high groundwater level areas," *Journal of Cleaner Production,* vol. 112, pp. 631-638, 2016.

[31] Z. Tang, W. Li, G. Ke, J. L. Zhou, and V. W. Tam, "Sulfate attack resistance of sustainable concrete incorporating various industrial solid wastes," *Journal of Cleaner Production,* vol. 218, pp. 810-822, 2019, doi: doi.org/10.1016/j.jclepro.2019.01.337

[32] BS, "Method for Determination of Compressive Strength of Concrete Cores, BSI, UK.," 1881: Part 120. 1983.

[33] M. Almohammad-albakkar and K. Behfarnia, "Effects of micro and nano-silica on the fresh and hardened properties of self-consolidating concrete," in *1st international conference on civil engineering, architecture, development and reconstruction of urban infrastructure in Iran. Tehran, Iran*, 2020.

[34] R. Zhong and K. Wille, "Deterioration of residential concrete foundations: The role of pyrrhotite-bearing aggregate," *Cement and Concrete Composites,* vol. 94, pp. 53-61, 2018, doi: 10.1016/j.cemconcomp.2018.08.012

[35] M. Cohen, "Modeling of expansive cements," *Cement and Concrete Research,* vol. 13, no. 4, pp. 519-528, 1983, doi: doi.org/10.1016/0008-8846(83)90011-X

[36] P. Metha and S. Wang, "Expansion of ettringite by water absorption," *Cement and Concrete Research,* vol. 12, no. 1, pp. 121-122, 1982.

[37] S. Diamond, "Delayed ettringite formation—Processes and problems," *Cement and concrete Composites,* vol. 18, no. 3, pp. 205-215, 1996, doi: doi.org/10.1016/0958-9465(96)00017-0

[38] P. Liu, Y. Chen, Z. Yu, and Z. Lu, "Effect of sulfate solution concentration on the deterioration mechanism and physical properties of concrete," *Construction and Building Materials,* vol. 227, p. 116641, 2019, doi: doi.org/10.1016/j.conbuildmat.2019.08.022

[39] G. Zhao, M. Shi, M. Guo, and H. Fan, "Degradation mechanism of concrete subjected to external sulfate attack: Comparison of different curing conditions," *Materials,* vol. 13, no. 14, p. 3179, 2020, doi: doi.org/10.3390/ma13143179

تقييم تأثير المياه الجوفية الملوثة بالملح المركب على مقاومة الضغط للأساسات الخرسانية: دراسة حالة في البصرة، العراق

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الملخص

تهدف هذه الدراسة إلى معرفة تأثير المياه الجوفية المحتوية على أملاح مركبة على مقاومة الضغط للأساسات الخرسانية الموجودة في مدينة البصرة في العراق. تُظهر المياه الجوفية في هذه المدينة تركيزات عالية من الأملاح، ولا سيما كميات كبيرة من أملاح المغنيسيوم والصوديوم والكالسيوم الموجودة بالقرب من سطح التربة. لتحقيق هذا الهدف، تم اختيار أساس في المدينة المذكورة، والذي تم إنشاؤه منذ عام 2012 ولا يزال غير مكتمل حتى يومنا هذا. يغطي الأساس المختار مساحة تقارب 2000 متر مربع. تم جمع العينات من سبع مناطق مختلفة، مع أخذ ثلاث عينات من كل منطقة، أدى إلى إجمالي 21 عينة. كانت المناطق المختارة هي الأكثر تأثراً بالمياه الجوفية، وتحديداً تلك الأقرب إلى التربة، مثل المناطق القريبة من الحواف أو الفتحات داخل الأساس. أظهرت نتائج اختبارات مقاومة الضغط التي أجريت على جميع العينات انخفاضًا ملحوظًا في مقاومة الضغط. في المتوسط، كشفت النتائج عن انخفاض بنسبة 30 ٪ في مقاومة الضغط، مما يسلط الضوء على التأثير الكبير للمياه الجوفية الملوثة بالملح المركب على ديمومة الأساسات الخرسانية.

الكلمات الداله:

المياه الجوفية الملوثة بالملح ؛ أساس خرساني؛ مقاومة الضغط؛ أملاح المغنيسيوم؛ أملاح الصوديوم و الكالسيوم.