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Characteristics of Concrete Exposure in The Marine Environment

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Abstract

The characteristics of concrete in the marine environment with various grades of concrete of grade 30, 35, and 40 investigate in this research. The objective of this study is to identify the optimum grade of concrete in the marine environment. Several test was conducted such as water absorption, density, ultrasonic pulse velocity (UPV), and compressive strength. The results show that the optimum grade of concrete in the marine environment is grade 40, which has the lowest water absorption of 8%, the highest density test of 2399 kg/m3, the highest UPV test result of 4723.249 m/s, and the highest compressive strength test of 31.63 MPa. The high result indicates the high quality and durability of the concrete. The study contributes to the understanding of the characteristics of concrete in the marine environment and provides valuable information for the selection of the appropriate grade of concrete for marine structures.

1. Introduction

The exposure of concrete structures to marine environments can result in a degradation process. The deterioration of concrete structures can be attributed to a variety of factors, including chemical reactions between cement hydration products and seawater constituents, the expansion of alkali-aggregates in the presence of reactive aggregates, crystallization pressures resulting from salt accumulation in concrete when one side of the structure is exposed to wetting and the other to drying conditions, the degradation caused by frost action in cold environments, the corrosion of embedded steel, and additional frost action in colder climates [1]. An assault originating from any of the aforementioned sources has a proclivity to augment the porosity of the material, thereby rendering it more susceptible to subsequent deterioration by the same deleterious factor [2].

The deleterious effects of saltwater on concrete must be recognized. After precisely determining the appropriate concrete mix design, it will facilitate the optimal durability of the concrete surface over a prolonged period. Concrete that is not protected from exposure to seawater can become damaged due to the various chemical and physical processes that are involved. The reduction of damage may be achieved by minimizing the degree of porosity within the concrete structure. A high-quality concrete mixture has the capability to eliminate potent chemical agents present in concrete, minimize the degree of soluble lime seepage, and reduce carbonation depth while protecting the steel frame against chemical-induced corrosion [3].

In the context of reinforced concrete exposed to marine environments, the presence of sodium chloride in particulate form poses a significant threat to the concrete's alkalinity levels, which results in accelerated deterioration of the steel reinforcement. The porosity of concrete shall be calculated by the infiltration of water, air, and supplementary elements, in particular chloride ions, into the concrete. The porosity of concrete facilitates the ingress of various substances while the presence of larger pores enhances the overall permeability of the material to the aforementioned substances. A densely structured concrete exhibiting minimal porosity is highly recommended for marine applications, as this feature can mitigate the deleterious consequences of sulphate attack and reduce the likelihood of corrosion on steel surfaces. The diverse regions of the marine environment that impact the degradation of concrete structures comprise locations where sea spray is present and the concentration of salts transported inland. The rise in such salt concentrations leads to precipitated salts of less than or equal to 10 μm and greater than 10 μm. As such, the process of corrosion occurs among steel materials situated at a distance of several hundred meters from the interior of the seashore [4].The objective of this study is to identify the optimum grade of concrete in the marine environment.

2. Materials and Methods

2.1 Preparation of Concrete Mixture

Twelve (12) cube moulds with the size of 150mm × 150mm × 150mm were prepared for the control sample. The moulds were oiled before casting. A mixture of 20.25 kg cement, 20.25 kg sand, 40.50 kg aggregate, and 9.11 kg water were prepared for 0.45 water-to-cement ratio. The mixture was poured and water added for desired consistency. The mixture was poured into the moulds and compacted to fill them properly. The process was repeated for the next samples. The control sample used a sand to cement ratio of 1:1.2 and a water to cement ratio of 0.45, typical for traditional cement mortar [5]. For the grade 35 concrete samples, 12 cube moulds (150mm × 150mm × 150mm) were prepared on the first day. The moulds were oiled and a mixture with 17.71 kg of cement, 30.36 kg of sand, 40.48 kg of sand, and 7.97 kg of water was prepared. The mixture was poured, water added, and poured into oiled moulds. It was compressed by stamping to fill the mould. The process was repeated for day two. Similarly, for the grade 40 concrete samples, the procedure was the same as the grade 35 and 30 samples. 12 cube moulds were initially prepared and coated with oil. A mixture was made with 22.77 kg of cement, 43.01 kg of sand, 32.89 kg of aggregate, and 10.25 kg of water.

2.2 Curing of Concrete Cubes

The customary methodology for curing concrete cubes entails submerging them in fresh water and maintaining them in such condition for a period of 28 days to achieve maximum strength of the concrete cubes. Following a duration of 28 days, the cubes are subsequently relocated to a seawater environment to undergo additional curing. The cubes undergo a curing process in seawater for varying durations of 30, 60, and 90 days. The assessment of concrete durability in marine environments is a critical factor that necessitates the consideration of curing processes in seawater [6].

Fig. 1 *Submerging the concrete sample in seawater at Kuala Perlis, Perlis*

2.3 Testing of Concrete Cubes

Several test such as water absorption, density, ultrasonic pulse velocity (UPV), and compressive strength of the concrete samples. By analysing the water absorption, density, UPV and compressive strength of concrete samples is essential for determining the quality and durability of concrete structures. Based on these properties, engineers can select the appropriate grade of concrete for specific applications and ensure that the concrete meets the required standards and specifications [7].

3. Results and Discussion

3.1 Relationship Between Ultrasonic Pulse Velocity and Density

The diagram depicted in Figure 2 illustrates the correlation existing among the grade of concrete, its UPV and its density. Based on the depicted graph, it can be observed that the values for both the UPV and the density demonstrate a consistent increase for concrete grades 30, 35, and 40, in sequential order. The observed increase in UPV values, as depicted in the provided figure, was observed to rise from 4955. 67 m/s for concrete grade 30 to 4963. 67 m/s for concrete grade 40. The rise in density is observed in a similar manner for both concrete grade 30 and grade 40, with an increase from 2280 kg/m3 to 2399 kg/m3, respectively.

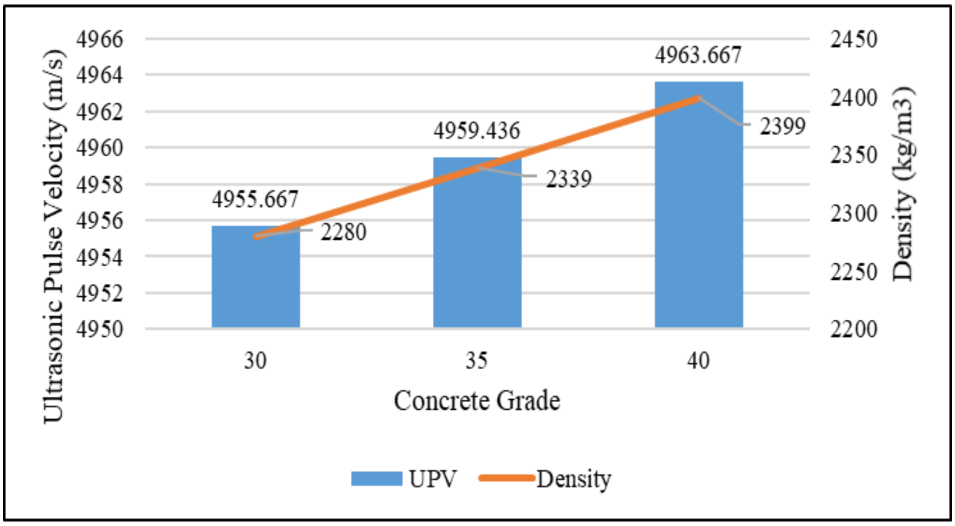

Fig. 2 *Relationship between ultrasonic pulse velocity and density for concrete grade 30, 35 and 40*

3.2 Relationship between Ultrasonic Pulse Velocity and Compressive Strength

The relationship between Ultrasonic Pulse Velocity (UPV) and compressive strength of concrete is a commonly studied and utilized correlation in the field of non-destructive testing. Observation from Figure 3,4 and 5 portrait the result of UPV test and compressive strength test on sea water curing of grade 30 concrete. The curing of the concrete was set for control that is 28 days in fresh water, 30, 60 and 90 days in seawater respectively. The graph from the figure indicates that the strength of the concrete that was cured in sea water decreases with time. The control concrete holds the highest strength even after tested by using UPV and compressive strength method with 4955.667 MPa and 33.676 m/s respectively. After curing in sea water, the concrete strength dropped to 4663.321 MPa of UPV and 21.432 m/s of compressive strength after 90 days. The same decrease in strength of concrete with other grades as shown in Figure 4 and 5.

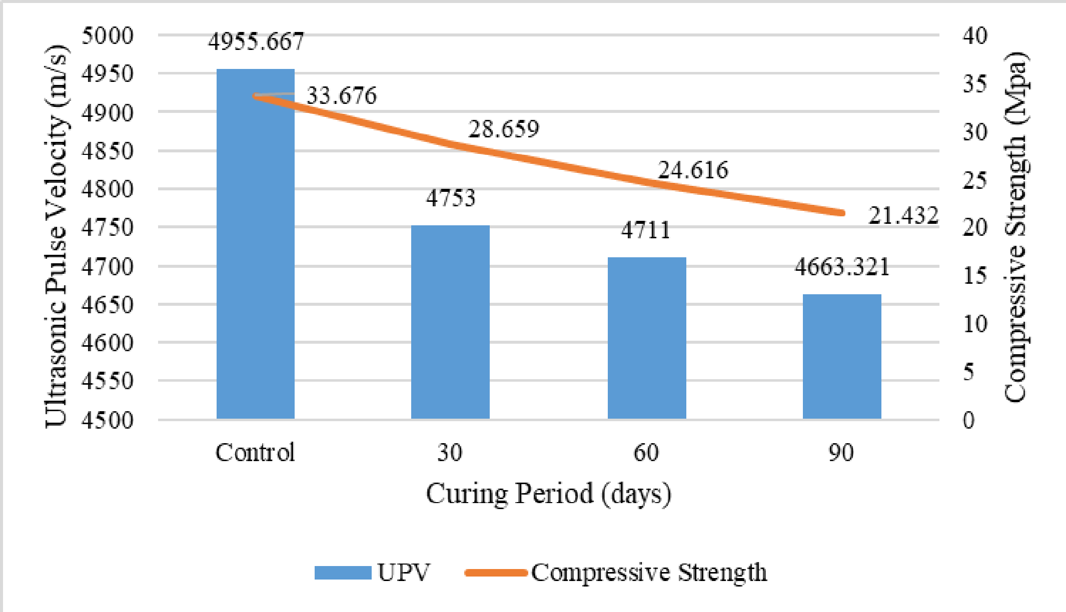

Fig. 3 *Relationship between ultrasonic pulse velocity and compressive strength for concrete grade 30*

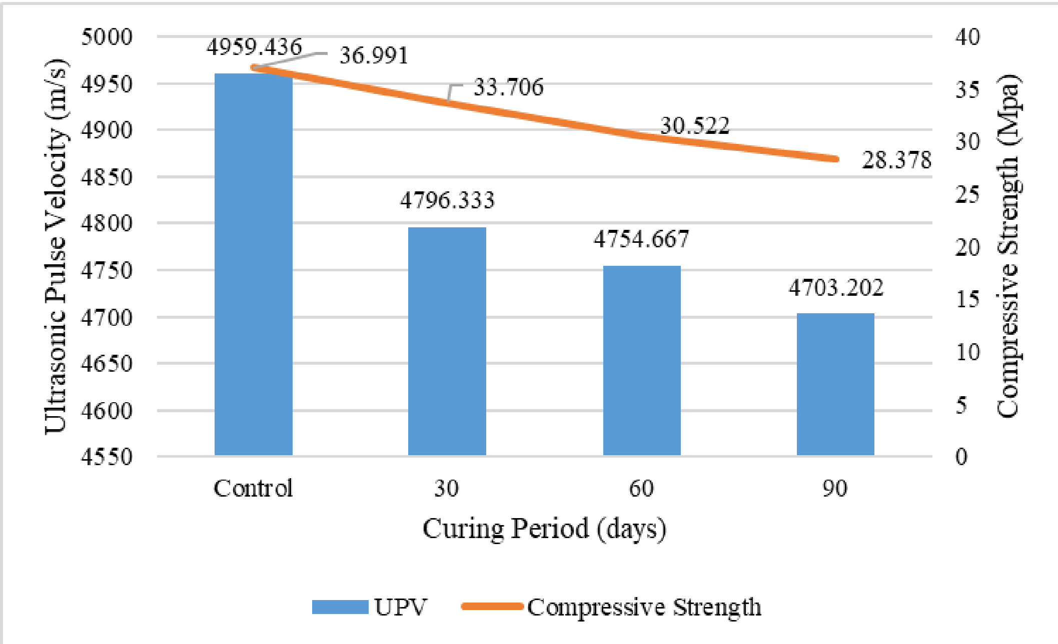

Fig. 4 *Relationship between ultrasonic pulse velocity and compressive strength for concrete grade 35*

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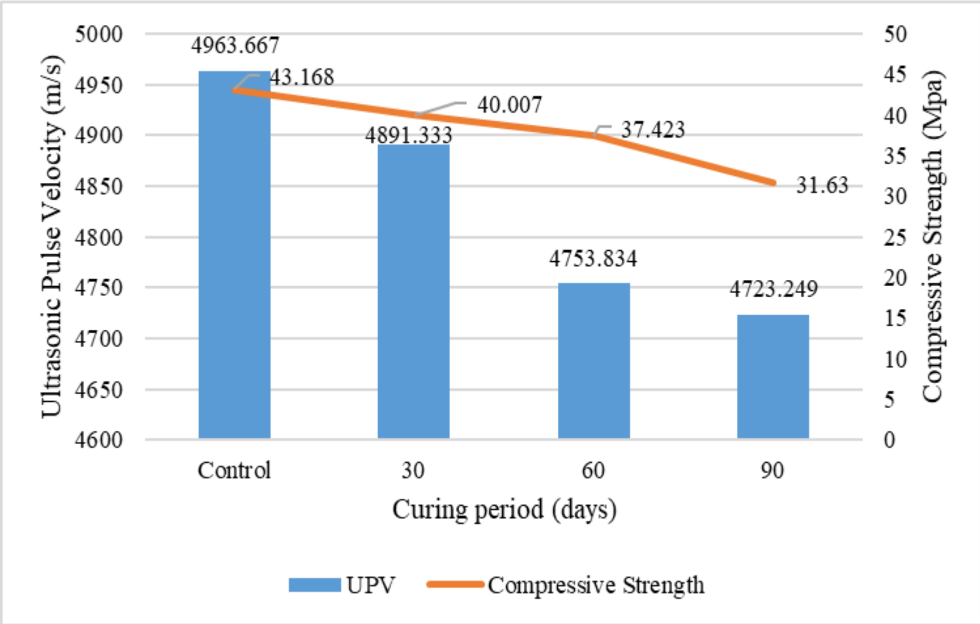

Fig. 5 *Relationship between ultrasonic pulse velocity and compressive strength for concrete grade 40*

3.3 Relationship Between Water Absorption and Compressive Strength

The decreasing of each compressive strength for concrete grade 30, 35 and 40 when the amount of water adsorption increases for each batch of 30, 60 and 90 days. Concrete grade 30 has the highest percent of water absorption after 90 days compare to concrete grade 35 and 40 that 21%, 28% and 32% subsequently. A low level of water absorption in concrete cubes has the potential to exert a positive influence on the compressive strength of concrete. This phenomenon occurs due to the decreased water absorption capacity, leading to a denser and stronger concrete matrix. The phenomenon of water absorption by concrete possesses the capability to produce empty spaces and weaken the bond between the cement and aggregate. The previously mentioned phenomenon has the potential to result in a reduction of both the compressive strength and durability of the concrete. When the water absorption in concrete grade 40 is minimal, the concrete matrix demonstrates increased density and decreased porosity, leading to improved compressive strength and durability of the concrete [8].

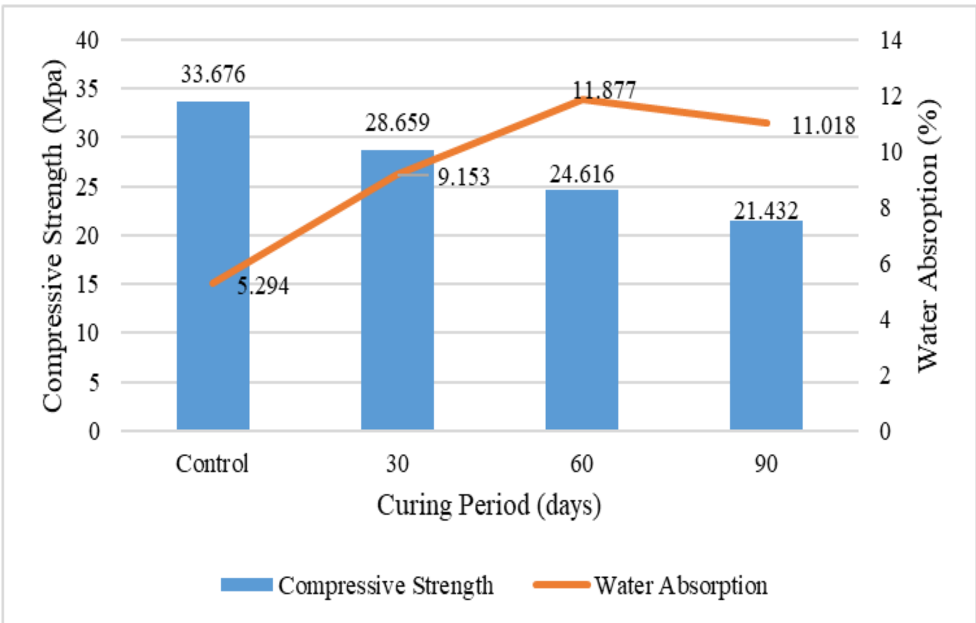

Fig. 6 *Relationship between water absorption and compressive strength for concrete grade 30*

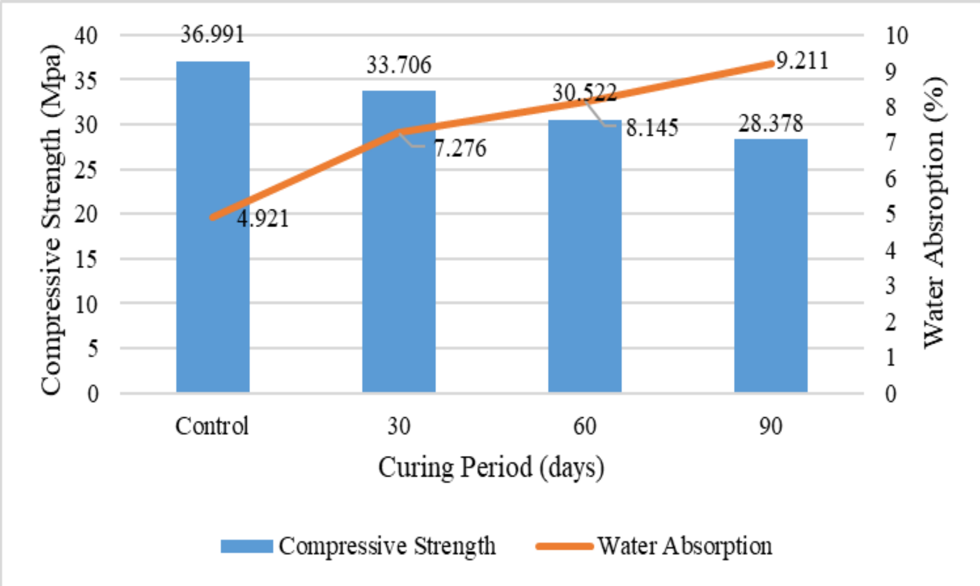

Fig. 7 *Relationship between water absorption and compressive strength for concrete grade 35*

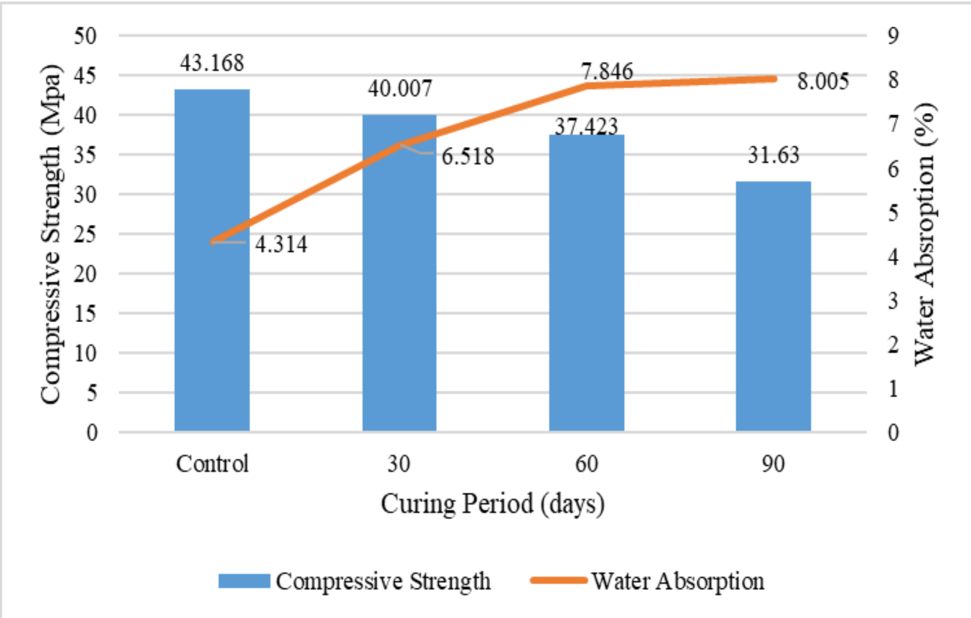

Fig. 8 *Relationship between water absorption and compressive strength for concrete grade 40*

3.4 Optimum Grade of Concrete

The selection of the optimum concrete grade can be accomplished by employing a range of assessments, such as the Ultrasonic Pulse Velocity (UPV) test, water absorption test, density test, and compressive strength test, which are carried out on concrete grades 30, 35, and 40, correspondingly. Higher velocities are an indication of enhanced quality and uniformity of the material, whereas lower velocities may imply the existence of multiple cracks or empty spaces in the concrete. The evaluation of concrete properties can be accomplished through the implementation of two distinct techniques, namely the water absorption test and the density test. The compressive strength test is a widely employed technique for ascertaining the upper limit of compressive load that a concrete sample can endure before reaching the point of failure [9]. The selection of the most appropriate concrete grade among grade 30, 35, and 40 can be established by evaluating their individual characteristics, ultimately concluding that grade 40 is the optimal choice

4. Conclusion

The findings of the study improve the understanding of the suitability and effectiveness of different types of concrete grades in marine environments, thereby enabling the determination of the most beneficial grade for such applications. Based on a comprehensive investigation and assessment of various concrete attributes, encompassing compressive strength, permeability, chloride penetration, and durability, with the aim of offering valuable insights into the effectiveness of different concrete grades in marine environments. The study inquiry has revealed that concrete of a higher grade, specifically grade 40, exhibits the optimum grade that has the best properties in terms of compressive strength and durability when subjected to marine environments. The use of higher cementitious content and lower water-cement ratio in high-quality concrete has been found to be correlated with increased resistance to chloride penetration and enhanced durability in the corrosive marine environment. The study provides suggestions for the most suitable choice of concrete grades in marine environments, considering diverse aspects such as strength requirements, durability, and resistance to chloride ingress. It is offers suggestions regarding the suitable selection of concrete grade in marine environments, considering diverse aspects such as strength, durability, and chloride penetration resistance, among others [10].

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***Characteristics of Concrete Exposure in the Marine Environment:*** *Mustaqqim Abdul Rahim, Nur Adlina Amri;* ***data collection:*** *Norlia Mohamad Ibrahim, Afizah Ayob, Shamshinar Salehuddin;* ***analysis and interpretation of results:*** *Nur Liza Rahim, Shahiron Shahidan;* ***draft manuscript preparation.*** *All authors reviewed the results and approved the final version of the manuscript.*

References

[1] The Editors of Encyclopaedia, “concrete -- Britannica Online Encyclopedia,” *concrete -- Britannica Online Encyclopedia*, 2023.https://doi.org/10.1080/10618562.2012.752573

[2] .Dimri, J. K. Varshney, V. K. Verma, and S. Gupta, “A Review on Strength of Concrete in Seawater.” [Online]. Available: www.ijert.org

[3] Corrosion Effects on the Durability of Reinforced Concrete Structures.” https://www.materialsperformance.com/articles/material-selection-design/2015/12/corrosion-effects-on-the-durability-of-reinforced-concrete-structures (accessed Jun. 08, 2023).

[4] M. Castillo, K. Hernández, J. Rodriguez, and C. Eyzaguirre, “Low Permeability Concrete for Buildings Located in Marine Atmosphere Zone using Clay Brick Powder,” in IOP Conference Series: Materials Science and Engineering, Institute of Physics Publishing, Feb. 2020. doi: 10.1088/1757-899X/758/1/012093.

[5] “Mortar mix proportions and quantities of constituent materials | Download Table.” https://www.researchgate.net/figure/Mortar-mix-proportions-and-quantities-of-constituent-materials_tbl1_49619589 (accessed Jun. 13, 2023).

[6] F. M. Wegian, “Effect of seawater for mixing and curing on structural concrete,” IES Journal Part A: Civil and Structural Engineering, vol. 3, no. 4, pp. 235–243, 2010, doi: 10.1080/19373260.2010.521048.

[7] A. A. Mohammed, S. K. Rafiq, and N. A. Hamid, “The assessment of concrete subjected to preloading using non destructive testing methods,” Case Studies in Construction Materials, vol. 15, Dec. 2021, doi: 10.1016/j.cscm.2021.e00705.

[8] O. Ofuyatan, A. Olowofoyeku, J. Oluwafemi, and J. Ighalo, “Predicting the Compressive Strength of Concrete By Ultrasonic Pulse Velocity,” *IOP Conf Ser Mater Sci Eng*, vol. 1036, no. 1, p. 012053, Mar. 2021, doi: 10.1088/1757-899X/1036/1/012053.

[9] A. M. Shende, A. M. Pande, and M. G. Pathan, “Experimental Study on Steel Fiber Reinforced Concrete for M-40 Grade,” 2012. [Online]. Available: www.irjes.comwww.irjes.com

[10] C. Andrade, A. Poursaee, and B. Ross, “The Role of Cracks in Chloride-Induced Corrosion of Carbon Steel in Concrete—Review,” *Corrosion and Materials Degradation 2022, Vol. 3, Pages 258-269*, vol. 3, no. 2, pp. 258–269, Jun. 2022, doi: 10.3390/CMD3020015