The Fourth Postgraduate Engineering Conference
IOP Conf. Series: Materials Science and Engineering 745 (2020) 012171
doi:10.1088/1757-899X/745/1/012171

Effect of Salinity on Concrete Properties

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Abstract. The attack of sulphate for concrete is one of the structural problems facing concrete works and has aroused the interest of researchers after the impact of this problem has appeared on many of the facilities. There are two sources of sulfur salts that attack the concrete which are external and internal, the external ones are found in the ground and surface water or the soil surrounding the concrete, the interior is within the structures of internal materials in concrete, such as aggregates, cement, water and additives. The presence of sulphate salts at high rates negatively affects the hardened cement paste due to the formation of additional quantities of Ettrengite where a large volume increase in the hardened cement paste leads to internal stresses causing cracks in the concrete mass affecting the resistance. The performance of concrete exposed to the attack of sulfur is divided into several different phenomena, such as concrete properties, absorption, and permeability. In the current investigation study, the impact of "saltwater" and "freshwater" on the characteristics of concrete (compressive strength, splitting tensile strength and flexural strength) are examined. Concrete cubes, prisms and cylinders were cast with normal concrete mix design were estimated. Different proportions of salt like (0, 10, 20, 30, 40 and 50) grams/ liter of water were examined. The concrete cubes, prisms, and cylinders were cured for 3, 7, 14 and 28 days with different salt proportions.

1. Introduction
Concrete is the common extensively utilized building and structural element across the world. It is challenging to decide-out substitute substances for installation with durability and economic [1]. The amount of water performs an essential function in the manufacture of concrete. Water impurities may conflict with the setting of the cement and may negatively influence the characteristics of strength. The chemical components existing in water may cooperate in the chemical reactions and consequently modify the hardening, setting, and strength advancement of the mixture. The earth’s surface (approximately 80%) is covered by oceans; consequently, a considerable number of constructions are revealed to the high salinity of seawater. The concrete durability relies on the water quality [2]. The principal seawater chemical elements are the "ions of chloride, potassium, calcium, sodium, and magnesium". The quantities of significant constituents of salt as 2.3%K2SO4, 3.9%CaSO4, 5%MgSO4, 10.5%MgCl, and 78%NaCl.

Concrete possesses superior fundamental production and durability however is influenced by initial deterioration during undergo to a marine climate. The ordinary traditional condition of deterioration is the steel reinforcement corrosion, jointly a succeeding concrete sapling. Consequently, the fundamental parameters in designing a durable marine structure concrete are the adoption of materials, design of mix, and individual reinforcement detailing [3]. The concrete durability is frequently considered as its strength to counter the impacts and environmental influences while achieving its in-demand purpose. Subsequently, chlorides can penetrate the concrete more immediately, however, carbon dioxide can likewise efficiently diffuse from the atmosphere, jointly, therefore, participate in the reinforcing steel corrosion [4].
The damage of concrete comes through the concrete structures service life related to chemical and physical offensive which managed through aggressive environments. Developing infrastructure improvement is in direction including the demands of every year clean water. An examination of freshwater conservations is extremely sincerely required. Furthermore, it is economical to utilize seawater that is accessible within easy reach of the installation locality alternatively of potable water to be deported from different area's sources. To nowadays, there are several researchers examined the durability performance of concrete produced including plain as well as seawater [5, 6].

2. Literature Review

The attack of sulphate for concrete is one of the structural problems facing concrete works and has aroused the interest of researchers after the impact of this problem has appeared on many of the facilities. Akinsola O et al. (2012) [3] used jointly ocean and lagoon water however freshwater was employed as a standard measure. The results exposed that concrete specimen molded and handled with freshwater achieved significant compressive strength up 150 days limit however specimen formed and handled with lagoon and ocean water moderately develop in strength except lower while correlated with freshwater reinforced concrete element. Preeti T et al. (2014) [2] investigate the impact of saltwater on the compressive strength of concrete. Outcomes revealed that an improvement in strength of the concrete cubes which were cast and handled with saltwater as correlated to freshwater. Nagabhushana et al. (2017) [4] study the influence of salt quantity of (25, 30, 35, 40, 45) grams/ litre of NaCl in concrete compressive strength, and revealed that an improvement in the concrete compressive strength for moderate percentage of salt content and there is reduction in compressive strength for raised percentage of salt content. Md Safiuddin (2017) [7] discussed the effects of concrete endurance, behavior standards, and behavior estimation techniques of concrete protection sealer and coating systems. Aiad H et al. (2013) [8] study the concrete attack with the impact of magnesium sulphate including cement additives materials on concrete properties like compressive strength. Qingyong G et al. (2018) [5] study the impact of seawater for mixing, curing on the increase in intensity in several classes of concrete. Sai T et al. (2014) [6] study the influence of varying salt percentages on the compressive strength of concrete (4, 10, 30, and 60g/L). Sreehari R et al. (2012) [9] examining the consequence of neutral salts on cements admixture with NACL as mixing water on compressive strength and setting times. Sathish K et al. (2018) [10] investigate the splitting, compressive and flexural strength with the effect of saltwater and freshwater on concrete. Sagar G et al. (2017) [11] study the (35 g/L) NaCl saltwater and freshwater on flexural and tensile strength beside compressive strength, split tensile strength of concrete. Olutoge F et al. (2014) [12] study the effect of freshwater and seawater with curing of 7, 14, 21, 28, and 90days on the compressive strength of concrete. Falah M (2010) [13] examine the concrete compressive strength with the consequences of curing and mixing with seawater and results revealed that a decrease in strength develops with an improvement in display time, which may be related to salt crystallization composition concerning the gain in strength. Agrawal A et al. (2017) [14] used two types of concrete, cured with freshwater and saltwater for 28 days, Rakesh A and Dube S (2014) [15] study on concrete compressive strength the effect of tap water, wastewater, well water, bore well water and mineral water.

3. Experimental Work Details and Description

The purposes of the experimental program are conducted to study the effects of saltwater and freshwater on the concrete properties (compressive strength, splitting tensile strength and flexural strength) [16]. The salt (NaCl) of various proportions like (0, 10, 20, 30, 40 and 50) grams/ liter of water was adopted and the concrete was cured in both freshwater and seawater. The concrete cubes, prisms, and cylinders were cured for 7, 14 and 28 days. The main details of the experimental program throughout this research are illustrated below. Tables 1 and 2 shows the details of types of mix used in the present research work and details of the present research work.

| Concrete type | Cement kg/m³ | Sand kg/m³ | Aggregate kg/m³ | w/c |
|---------------|--------------|------------|-----------------|-----|
| Normal Concrete | 420          | 650        | 1000            | 0.45 |
### Table 2. Details of experimental work.

| Group | Salt content | Test Duration | Test Type | Type of test |
|-------|--------------|---------------|-----------|--------------|
| Group 1 | 0%           | 3 days        | Compression, Splitting and Flexure | 3 cylinders and cubes and prism for each mix |
|        |              | 7 days        | Compression, Splitting and Flexure | 3 cylinders for each mix |
|        |              | 14 days       | Compression, Splitting and Flexure | 3 Prism for each mix |
|        |              | 28 days       | Compression, Splitting and Flexure | 100diamx200 height |
|        |              | 7 days        | Compression, Splitting and Flexure | 100*100*400 cube |
| Group 2 | 1.0%         | 3 days        | Compression, Splitting and Flexure | 100diamx200 height |
|        |              | 7 days        | Compression, Splitting and Flexure | 100*100*400 cube |
|        |              | 14 days       | Compression, Splitting and Flexure | 100diamx200 height |
|        |              | 28 days       | Compression, Splitting and Flexure | 100*100*400 cube |
| Group 3 | 2.0%         | 3 days        | Compression, Splitting and Flexure | 100diamx200 height |
|        |              | 7 days        | Compression, Splitting and Flexure | 100*100*400 cube |
|        |              | 14 days       | Compression, Splitting and Flexure | 100diamx200 height |
|        |              | 28 days       | Compression, Splitting and Flexure | 100*100*400 cube |
| Group 4 | 3.0%         | 3 days        | Compression, Splitting and Flexure | 100diamx200 height |
|        |              | 7 days        | Compression, Splitting and Flexure | 100*100*400 cube |
|        |              | 14 days       | Compression, Splitting and Flexure | 100diamx200 height |
|        |              | 28 days       | Compression, Splitting and Flexure | 100*100*400 cube |
| Group 5 | 4.0%         | 3 days        | Compression, Splitting and Flexure | 100diamx200 height |
|        |              | 7 days        | Compression, Splitting and Flexure | 100*100*400 cube |
|        |              | 14 days       | Compression, Splitting and Flexure | 100diamx200 height |
|        |              | 28 days       | Compression, Splitting and Flexure | 100*100*400 cube |
| Group 6 | 5.0%         | 3 days        | Compression, Splitting and Flexure | 100diamx200 height |
|        |              | 7 days        | Compression, Splitting and Flexure | 100*100*400 cube |
|        |              | 14 days       | Compression, Splitting and Flexure | 100diamx200 height |
|        |              | 28 days       | Compression, Splitting and Flexure | 100*100*400 cube |

### 4. Mixing procedure
Throughout the research work (ASTM Type I) ordinary Portland cement was used in casting all specimens. Normal sand as fine aggregate is used here which follows with [B.S. and Iraqi No.882/1992 and No.45/1984 and ASTM-C33M-08]. According to the normal concrete mixture, the well-graded natural aggregate of ultimate dimension (10mm) was used to guarantee satisfactory workability. Aggregates were washed, dried and stored in dry condition before being used. Concrete is poured normally where dry materials are initially mixed from cement, sand, and gravel for a certain period and then added the water to obtain a homogeneous mixture. After finishing the casting process, the homogeneous mixture is distributed to the molds where it is filled with three layers and vibrate using shakers to remove the air from the concrete to obtain a homogeneous casting [17, 18]. The surface of the molds shall be modified and covered to prohibit the water evaporation from the concrete for a whole day and then taken out of the forms and placed in water with different salts percentage containers for 3, 7, 14 and 28 days after which they are taken out in preparation for the examination day as shown in Figure 1.

![Figure 1. Mixing of Concrete, casting and curing.](image-url)
5. Hardened Compressive strength Concrete characteristics

Compressive strength represents the common essential properties of hardened concrete and is the characteristic material value for the analysis of concrete in national and universal codes. The compressive strength experiment was planned according to [B.S-1881; part 116] and with [ASTM C39-2005]. Each specimen (cubes 100x100mm and cylinder 100*200mm) were brought out of the treating tank and placed in the compression machine. The mean of three specimens was adopted to achieve the average compressive strength as demanded by [ACI 318M Code].

6. Hardened Flexural Strength Properties of Concrete

The standard test for flexural strength [ASTM C1018], which states testing simply supported prism (100x100x400 mm) were provided approve to the [ASTM C 348-02] specification. The simply supported prisms were examined utilizing two points load with a clear span of 210 mm and 300mm. They were examined at the age of 3, 7, 14 and 28 days and the mean of three specimen's results was selected for each test.

7. Hardened Splitting Tensile Strength Properties of Concrete

The splitting tensile strength experiment was handled on cylinders of (100×200mm). Cylinders were tested at 3, 7, 14 and 28 days and the standard of splitting tensile strength of three cylinders was adopted for every mix following [ASTM specification C496-04] using the same machine as for compressive strength.

8. Results and Discussion of Strength and Hardened Properties of Concrete

Results obtained from the laboratory are presented here. All work were investigated over a period of 3, 7, 14 and 28 days as shown in Tables 3 and 4 and Figures 2, 3 and 4. Seawater effects in the strength of concrete when employed for curing. It presents remarkable improvements at some level but eventually decreases the strength. Three main properties of hardened concrete are considered, they are the compressive strength, splitting tensile strength and flexural tensile strength. For each of these properties, the average values of the three specimens were obtained. Table 5 and Figures 5-16 shows all the relationship of concrete properties for all test with test duration groups.

Table 3. Strength and Mechanical Properties of Hardened Concrete.

| Concrete type | Fc cube (MPa) | Fc cylinder (MPa) | splitting tensile strength (MPa) | Flexural tensile strength (MPa) | (%) compressive strength | (%) splitting tensile strength | (%) flexural tensile strength |
|---------------|---------------|------------------|---------------------------------|-------------------------------|--------------------------|-----------------------------|-----------------------------|
| Normal concrete | 34            | 30               | 3.60                            | 4.3                           |                          |                             |                             |

Table 4. All mechanical Properties of Hardened Concrete.

| Group | Salt content | Test Duration | Cylinder compressive strength (MPa) | Splitting tensile strength (MPa) | Flexural tensile strength (MPa) | (%) compressive strength | (%) splitting tensile strength | (%) flexural tensile strength |
|-------|--------------|---------------|-----------------------------------|---------------------------------|-------------------------------|--------------------------|-----------------------------|-----------------------------|
| Group 1 | 0%          | 3            | 14.0                              | 1.7                             | 2.00                          | 0.00                     | 0.00                         | 0.0                         |
|       | 7            | 18.0         | 2.30                              | 2.70                            | 0.00                          | 0.00                     | 0.00                         | 0.0                         |
|       | 14           | 24.0         | 3.00                              | 3.60                            | 0.00                          | 0.00                     | 0.00                         | 0.0                         |
|       | 28           | 30.0         | 3.60                              | 4.50                            | 0.00                          | 0.00                     | 0.00                         | 0.0                         |
| Group 2 | 1.00%       | 3            | 13.9                              | 1.69                            | 1.97                          | -0.71                    | -0.59                        | -1.50                       |
|       | 7            | 17.9         | 2.28                              | 2.68                            | -0.56                         | -0.87                    | -0.74                        | -0.74                       |
|       | 14           | 24.2         | 3.00                              | 3.65                            | 0.83                          | 0.00                     | 1.39                         | 1.39                       |
|       | 28           | 27.6         | 3.50                              | 4.15                            | -8.00                         | -7.89                    | -7.78                        | -7.78                       |
| Group 3 | 2.00%       | 3            | 14.0                              | 1.68                            | 2.00                          | 0.00                     | -1.18                        | 0.00                         |
|       | 7            | 17.9         | 2.27                              | 2.66                            | -0.56                         | -1.30                    | -1.48                        | -1.48                       |
|       | 14           | 24.3         | 3.00                              | 3.66                            | 1.25                          | 0.00                     | 1.67                         | 1.67                       |
|       | 28           | 27.8         | 3.42                              | 4.00                            | -7.33                         | -10.00                   | -11.11                       | -11.11                      |
| Group 4 | 3.00%       | 3            | 13.9                              | 1.66                            | 1.98                          | -0.71                    | -2.35                        | -1.00                       |
|       | 7            | 17.6         | 2.20                              | 2.60                            | -2.22                         | -4.35                    | -3.70                        | -3.70                       |
|       | 14           | 23.9         | 3.10                              | 3.70                            | -0.42                         | 3.33                     | 2.78                         | 2.78                       |
|       | 28           | 27.3         | 3.40                              | 3.97                            | -9.00                         | -10.53                   | -11.78                       | -11.78                      |
| Group 5 | 4.00%       | 3            | 13.0                              | 1.64                            | 1.98                          | -7.14                    | -3.53                        | -1.15                       |
|       | 7            | 17.3         | 2.15                              | 2.57                            | -3.89                         | -6.52                    | -4.81                        | -4.81                       |
|       | 14           | 23.3         | 2.98                              | 3.60                            | -2.92                         | -0.67                    | 0.00                         | 0.00                       |
|       | 28           | 26.7         | 3.39                              | 3.92                            | -11.00                        | -10.79                   | -12.89                       | -12.89                      |
| Group 6 | 5.00%       | 3            | 12.4                              | 1.62                            | 1.95                          | -11.43                   | -4.71                        | -2.50                       |
|       | 7            | 15.8         | 2.10                              | 2.50                            | -12.22                        | -8.70                    | -7.41                        | -7.41                       |
8.1 For salt content of (1.0%)
1-for compressive strength when adding (1.0%) salt content a decreasing in compressive strength of about (0.71, 0.56, 0.83 and 8%) for 3, 7, 14 and 28-day duration of curing.
2-for splitting tensile strength when adding (1.0%) salt content a decreasing in splitting tensile strength of about (0.59, 0.87, 0, 7.89 %) for 3, 7, 14 and 28-day duration of curing.
3-for flexural tensile strength when adding (1.0%) salt content a decreasing in flexural tensile strength of about (1.5, 0.74, and 7.78%) for 3, 7 and 28-day duration of curing and an increasing of about (1.39%) for 14-day.

8.2 For salt content of (2.0%)
1-for compressive strength when adding (2.0%) salt content a decreasing in compressive strength of about (0, 0.56 and 7.33%) for 3, 7 and 28-day duration of curing and an increasing of about (1.25%) for 14-day.
2-for splitting tensile strength when adding (2.0%) salt content, decreasing in splitting tensile strength of about (1.18, 1.30, 0 and10.0%) for 3, 7, 14 and 28-day duration of curing.
3-for flexural tensile strength when adding (2.0%) salt content, decreasing in flexural tensile strength of about (0, 1.48, 11.11%) for 3, 7 and 28-day duration of curing and an increasing of about (1.67%) for 14-day.

8.3 For salt content of (3.0%)
1-for compressive strength when adding (3.0%) salt content a decreasing in compressive strength of about (0.71, 2.22, 0.42 and 9.0%) for 3, 7, 14 and 28-day duration of curing.
2-for splitting tensile strength when adding (3.0%) salt content a decreasing in splitting tensile strength of about (2.35, 4.35, and 10.53%) for 3, 7 and 28-day duration of curing and an increasing of about (3.33%) for 14-day.
3-for flexural tensile strength when adding (3.0%) salt content a decreasing in flexural tensile strength of about (1.0, 3.7, and 11.78%) for 3, 7 and 28-day duration of curing and an increasing of about (2.78%) for 14-day.

8.4 For salt content of (4.0%)
1-for compressive strength when adding (4.0%) salt content a decreasing in compressive strength of about (7.14, 3.89, 2.92 and 11%) for 3, 7, 14 and 28-day duration of curing.
2-for splitting tensile strength when adding (4.0%) salt content a decreasing in splitting tensile strength of about (3.53, 6.52, 0.67 and 10.79%) for 3, 7, 14 and 28-day duration of curing.
3-for flexural tensile strength when adding (4.0%) salt content a decreasing in flexural tensile strength of about (1.15, 4.81, 0 and 12.89%) for 3, 7, 14 and 28-day duration of curing.

8.5 For salt content of (5.0%)
1-for compressive strength when adding (5.0%) salt content a decreasing in compressive strength of about (11.43, 12.22, 11.67 and 13.0%) for 3, 7, 14 and 28-day duration of curing.
2-for splitting tensile strength when adding (5.0%) salt content a decreasing in splitting tensile strength of about (4.71, 8.7, 3.33 and 11.84%) for 3, 7, 14 and 28-day duration of curing.
3-for flexural tensile strength when adding (5.0%) salt content a decreasing in flexural tensile strength of about (2.5, 7.41, 2.78 and 13.78%) for 3, 7, 14 and 28-day duration of curing.
Figure 2. Compressive strength for all test results.

Figure 3. Splitting tensile strength for all test results.

Figure 4. Flexural tensile strength for all test results.

Table 5. Concrete properties for all test with test duration groups.

| Group | Salt content | Test Duration | Cylinder compressive strength (MPa) | Splitting tensile strength (MPa) | Flexural tensile strength (MPa) |
|-------|--------------|---------------|------------------------------------|----------------------------------|-------------------------------|
| Group 1 | 0            | 3             | 14.0                               | 1.7                              | 2                             |
| Group 2 | 1            | 3             | 13.9                               | 1.69                             | 1.97                          |
| Group 3 | 2            | 3             | 14.0                               | 1.68                             | 2                             |
| Group 4 | 3            | 3             | 13.9                               | 1.66                             | 1.98                          |
| Group 5 | 4            | 3             | 13.0                               | 1.64                             | 1.98                          |
| Group 6 | 5            | 3             | 12.4                               | 1.62                             | 1.95                          |
| Group 1 | 0            | 7             | 18.0                               | 2.3                              | 2.7                           |
| Group 2 | 1            | 7             | 17.9                               | 2.28                             | 2.68                          |
| Group 3 | 2            | 7             | 17.9                               | 2.27                             | 2.66                          |
| Group 4 | 3            | 7             | 17.6                               | 2.2                              | 2.6                           |
| Group 5 | 4            | 7             | 17.3                               | 2.15                             | 2.57                          |
| Group 6 | 5            | 7             | 15.8                               | 2.1                              | 2.5                           |
| Group 1 | 0            | 14            | 24.0                               | 3                                | 3.6                           |
| Group 2 | 1            | 14            | 24.2                               | 3                                | 3.65                          |
| Group 3 | 2            | 14            | 24.3                               | 3                                | 3.66                          |
| Group 4 | 3            | 14            | 23.9                               | 3.1                              | 3.7                           |
| Group 5 | 4            | 14            | 23.3                               | 2.98                             | 3.6                           |
| Group 6 | 5            | 14            | 21.2                               | 2.9                              | 3.5                           |
| Group 1 | 0            | 28            | 30.0                               | 3.8                              | 4.5                           |
| Group 2 | 1            | 28            | 27.6                               | 3.5                              | 4.15                          |
| Group 3 | 2            | 28            | 27.8                               | 3.42                             | 4                             |
| Group 4 | 3            | 28            | 27.3                               | 3.4                              | 3.97                          |
| Group 5 | 4            | 28            | 26.7                               | 3.39                             | 3.92                          |
| Group 6 | 5            | 28            | 26.1                               | 3.35                             | 3.88                          |
Figure 5. Compressive strength of 3-day duration of curing for all salt content.

Figure 6. Splitting tensile strength of 3-day duration of curing for all salt content.

Figure 7. Flexural tensile strength of 3-day duration of curing for all salt content.

Figure 8. Compressive strength of 7-day duration of curing for all salt content.

Figure 9. Splitting tensile strength of 7-day duration of curing for all salt content.
Figure 10. Flexural tensile strength of 7-day duration of curing for all salt content.

Figure 11. Compressive strength of 14-day duration of curing for all salt content.

Figure 12. Splitting tensile strength of 14-day duration of curing for all salt content.

Figure 13. Flexural tensile strength of 14-day duration of curing for all salt content.

Figure 14. Compressive strength of 28-day duration of curing for all salt content.
9. Conclusions

1. External and internal sources of salts that attack the concrete were found internally in concrete materials used and externally in the surface and soil surrounding the concrete. The present research work tries to give a saltwater effect map on the main concrete properties with different salts percentage and curing durations.

2. It is reasonable to utilize seawater that is accessible near the building sites where a high constructions number are exposed to seawater with high salinity either instantly, or incidentally and were freshwater maintenances are extremely thoughtfully demanded.

3. Concrete degrades early despite possessing exceptional structural performance and durability during revealed to a marine environment. The strength of concrete to withstand the impacts of the environment and its effects is recognized as an example of the various essential characteristics of the strength of concrete through the performance of its expected function.

4. Steel reinforcing bar corroded at a pH of 11, was the seawater pH value ranges within 7.4 and 8.4. Seawater ought a complete salinity of approximately 3.5% (78% of the dissolved solids denoting NaCl and 15% MgCl2 and MgSO4), and provides an insignificantly higher initial intensity except a moderate long-term durability. The cement must supply alkalinity, in situations where concrete is constrained to an extremely critical conditions.

5. In present investigation analysis, the effects of freshwater and saltwater on the concrete properties (compressive strength, splitting tensile strength and Flexural strength) are investigated. For each of these properties, the average values of the three specimens were obtained. Concrete cubes, prisms and cylinders were cast for a normal mix design was estimated. The salt of multiple proportions like (0, 10, 20, 30, 40 and 50) grams/ liter of water were adopted. The concrete cubes, prisms, and cylinders were cured for 3, 7, 14 and 28 days.

6. Results show that for 3 days of curing and all salts content the compressive strength and flexural strength decreased with the increase in salts content, except for 2% there are no changes in the strength for both properties. While a decreasing in strength for all salts content for splitting tensile strength.

7. Results show that for 7 days of curing and all salts content the compressive strength, splitting tensile and flexural strength decreased with the increase in salts content.

8. Results show that for 14 days of curing the compressive strength increase with (1 and 2%) of salts content, the flexural strength increase with (1, 2 and 3%) and didn’t change with (4%) of...
salt content, finally the splitting tensile strength didn’t change with (2 and 3%) and increase with (3%) of salt content.

9. Experimental test results agree with other research’s study that shows some increases in concrete properties at some level of curing but ultimately a decrease in the concrete strength with 28 days of curing were adopted. Finally a decreasing in compressive strength of about (13.0%), a decreasing in splitting tensile strength of about (11.84%), and a decreasing in flexural tensile strength of about (13.78%) for 28-day duration of curing were concluded in the present research work.

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