Research Article

Resistance of Recycled Aggregate Concrete (RAC) Subjected to Drying-Wetting Cycles to Attack of Magnesium and Sodium Sulfates

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Recycled aggregates were widely used in the concrete industry as a replacement of natural aggregates in the last two decades. In this study, the resistance of concrete mixtures having various levels of recycled aggregate as a replacement of natural coarse aggregate to the attack of magnesium and sodium sulfates was investigated. Five mixtures made with 0%, 25%, 50%, 75%, and 100% recycled aggregate were partially immersed in magnesium and sodium sulfate solutions having concentrations of 2.5%, 4.5%, and 6.5% and subjected to drying-wetting cycles for a total of 10 weeks. Mass losses of concrete specimens owing to the attack of sulfate solutions and the effect of drying-wetting cycles were recorded weekly. Results show that the incorporation of recycled aggregate decreased the compressive strength of concrete at ages of 7 and 28 days. The decline in the compressive strength was more significant when the replacement percentage exceeds 50%. Mass losses of concrete specimens were found to be increased as the level of recycled aggregate increased. Mass losses of concrete specimens having 100% recycled aggregate were approximately as twice as those of concrete specimens having 0% recycled aggregate owing to 10 weeks of partial immersion in magnesium sulfate solutions of concentrations of 2.5%, 4.5%, and 6.5%. The attack of sodium sulfates was less aggressive than that of the magnesium sulfates. Results also show that the reduction in the compressive strength is directly proportional to the mass loss following a linear equation of R-squared value of 0.937.

1. Introduction

After 2003 and because of the unstable security situation in Iraq, hundreds and thousands of concrete walls were manufactured and used to protect the government and private buildings. Moreover, concrete walls were also used to separate residential quarters and sections in Baghdad and some other cities. Each concrete wall is about three cubic meters in volume and approximately 7000 kg in weight. Unfortunately, there is no accurate number of concrete walls used since 2003, but it can be predicted to be more than million units. In addition, many old buildings and structures were demolished and new ones were constructed after 2003 owing to the enhancement of the economic situation. Now, Iraq faces a substantial problem in depositing the waste concrete remaining. A solution which is beneficial and necessary from the viewpoint of environmental preservation and effective utilization of resources is applying recycled aggregates (RAs) as a replacement of natural aggregate in production of concrete [1, 2]. It is worth mentioning that the use of RA is not new in the construction industry. It was stated that Romans used stones from demolished roads in rebuilding of new roads [3]. Moreover, since the end of the World War II, the recycling industry had been well established in Europe [4].

The effect of using RA, as a partial or complete replacement of coarse aggregate, on different properties of concrete was extensively investigated by many research studies. The strength characteristics of concrete incorporating RA is highly influenced by the strength of the original concrete, the ratio of coarse to fine aggregates in the original concrete, and the ratio of the top size in the original concrete.
2.1.1. Cement. Ordinary Portland cement (OPC), ASTM C150 Type I, obtained from the local market, was used in preparation of all mixtures. Table 1 shows some physical and chemical properties of the cement used.

2.1.2. Aggregates. Natural coarse and fine aggregates obtained from a local quarry were used in preparation of concrete specimens. Particle size distributions of both fine and coarse aggregates are shown in Figure 1, while Table 2 depicts physical properties and results of some tests performed on the natural fine and coarse aggregates.

Unbroken concrete cubes available in different projects were used as a source of recycled aggregates (RAs). The cubes were first broken using the press machine and then additionally broken into small pieces using manual hammer. The RAs were sieved on 20 mm opening sieve to isolate the oversize pieces. The average compressive strength of cubes used as a source of RA was 37.2 MPa with a standard deviation of 7.5%. Grain size distribution and physical properties of RA are also shown in Figure 1 and Table 2, respectively.

2.1. Materials

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2.2. Concrete Mixtures. The reference mixture (M0) was produced using Type I cement and natural fine and coarse aggregates. The reference mixture was designed according to American Method of Selection of Mix Proportions ACI 211.1 with targeted 28-day compressive strength of 30 MPa. Four levels (25%, 50%, 75%, and 100%) of recycled aggregate were used as a replacement of natural coarse aggregate to produce the modified mixtures M25, M50, M75, and M100, respectively. Thus, a total of five concrete mixtures (M0, M25, M50, M75, and M100) were prepared to study the effect of recycled aggregate on compressive strength of concrete and to investigate the resistance of concrete incorporating recycled aggregate to sulfate attack. The mix proportion of the reference and modified mixtures is provided in Table 3.

A superplasticizer SP Mega flow complying with ASTM C494 was used in all mixtures to keep the slump of the mixtures with the range of 75 ± 25 mm.

Twenty-four cubes (150 × 150 × 150 mm) from each of the five mixtures were made and cured as per ASTM C192 and C172, respectively. Six of the twenty-four specimens were used to determine the compressive strength of each concrete mixture at age of 7 and 28 days (three specimens at each date). The remaining eighteen specimens were used for the sulfate attack testing program (three specimens for each of the six sulfate concentrations).

2.3. Sulfate Solution Baths. Three different concentrations (2.5%, 4.5%, and 6.5%) of magnesium sulfate and same three concentrations of sodium sulfate were used in this investigation to determine the response of concrete having recycled aggregate to sulfate attack. The solution of each concentration was prepared by mixing predetermined distilled water with sulfate powder corresponding to the required concentration. Six steel containers were manufactured with dimensions of 1000 × 1000 × 150 mm to hold the six solutions (one container for each sulfate concentration).
concentration). Each container was filled by a designed sulfate solution to the depth of 60 mm so that the concrete specimens will be partially immersed in the sulfate solution. It should be stated that the selected concentrations were reported to be present in groundwater and soils of Iraq [27]. To avoid changing of the designated concentration because of evaporation, each sulfate solution was replaced weekly by new solution with the same designated concentration.

### Table 1: Some physical and chemical properties of cement used.

| Chemical properties | Physical properties          |
|---------------------|-----------------------------|
| CaO                 | 62.61%                      |
| SiO₂                | 18.79%                      |
| Al₂O₃               | 4.79%                       |
| Fe₂O₃               | 3.48%                       |
| MgO                 | 2.35%                       |
| K₂O                 | 0.09%                       |
| Na₂O                | 0.18%                       |
| SO₃                 | 2.47%                       |
| Loss on ignition (L.O.I) | 3.00%            |
| Insoluble residue   | 1.28%                       |

### Table 2: Physical properties and results of some tests of fine and coarse aggregates and recycled aggregates.

| Properties                  | Fine aggregate | Natural coarse aggregate | Recycled coarse aggregate |
|------------------------------|----------------|--------------------------|---------------------------|
| Specific gravity             | 2.65           | 2.66                     | 2.53                      |
| Fineness modulus             | 2.35           |                          |                           |
| Absorption %                 | 1.60           | 5.91                     | 5.91                      |
| Sulfate content (SO₃) %      | 0.32           | 0.10                     | 0.1                       |
| Clay %                       | 2.30           |                          |                           |

### Table 3: Mix proportions of reference and modified concrete mixtures.

| Mixture ID | Cement content | Mix proportions kg/m³ |
|------------|----------------|-----------------------|
| M0 (ref.)  | 380            | Water 720, Sand 1052, Natural coarse aggregate 263 |
| M25        | 380            | Water 720, Sand 789, Natural coarse aggregate 263 |
| M50        | 380            | Water 720, Sand 526, Natural coarse aggregate 526 |
| M75        | 380            | Water 720, Sand 263, Natural coarse aggregate 789 |
| M100       | 380            | Water 720, Sand 1052, Natural coarse aggregate 1052 |

Figure 1: Grain size distribution of sand, natural coarse aggregate, and recycled aggregates.
During the testing program, all containers were kept in a controlled climate of 25°C temperature and 70 ± 10% humidity. Figure 2 shows the steel containers used in the sulfate attack testing program.

2.4. Testing Procedure. All concrete specimens were removed from the steel molds one day after casting and were transferred to the curing room (temp. 23°C and humidity > 95%). Concrete specimens used for sulfate attack testing program were cured for 28 days, whereas those used for compressive strength were kept until testing.

Fifteen concrete specimens (three of each concrete mixture) were tested at age of 7 days and the same numbers of concrete specimens were tested at age of 28 days to determine the effect of recycled aggregate on compressive strength of concrete. As per ASTM C39 guidelines, a press machine of loading rate 14.4 MPa/min was used to perform the compressive strength tests.

After the completion of the 28-day curing time, the concrete specimens used in the sulfate test program were dried in the oven (temp. 100°C) for one hour, accurately weighed, and cooled at room temperature prior to partially being immersed in the sulfate solutions. Fifteen concrete specimens (three specimens of each concrete mixture) were partially immersed in each solution. At the end of each week of the testing period, the concrete specimens were removed from the solution, rinsed by distilled water, dried at 100°C until constant weight, cooled at room temperature, and subsequently re-immersed in the new fresh solution. The testing program was terminated after ten weeks of testing. Mass losses occurred in concrete specimens owing to sulfate attack were recorded weekly during the testing program using the following equation:

\[ W = \left( \frac{m_0 - m_n}{m_0} \right) \times 100\% , \]  

where \( W \) is the mass loss of the specimen during a certain testing age and \( m_0 \) and \( m_n \) are the mass of the specimens before and after immersion in sulfate solutions, respectively. It should be noted that the wetting/drying cycles can initiate their own degradation and also accelerate the effect of the sulfate solution attack [20].

The compressive strength of the concrete specimens degraded by the sulfate attack was measured at the end of the testing program to determine the reduction in compressive strength owing to the sulfate attack. The reduction in the compressive strength \( (R) \) was calculated as follows:

\[ R = \frac{f_c(28 \text{ days}) - f_c(\text{after exposure})}{f_c(28 \text{ days})} \times 100\% . \]  

3. Results and Discussion

3.1. Effect of RA on Compressive Strength. Compressive strengths of the reference mixture (M0) and those of mixtures having various levels of recycled aggregate as replacement of natural coarse aggregate (25%, 50%, 75%, and 100%) were measured at ages of 7 and 28 days, and the results are provided in Table 4. It can be seen that the incorporation of recycled aggregate decreased the compressive strength. The decrease in the compressive strength was proportional to the replacement percentage of recycled aggregates. The reduction in compressive strength at ages 7 and 28 days was more significant when the replacement by RA exceeds 50%. The 7-day compressive strength was decreased by 26.7% and 44.4% owing to replacement of natural coarse aggregate by 75% and 100% recycled aggregate, respectively. The effect of recycled aggregate on compressive strength was less significant at age of 28 days than that at 7 days. The reduction in the 28-day compressive strength, as a result of 75% and 100% replacement by RA, was 20.5% and 25.2%, respectively.

The relationship between the replacement percentage of RA and the reduction in compressive strength at ages of 7 and 28 days is shown in Figure 3. It is clear that the reduction ratio increased as the replacement percentage increased. The figure also shows that the effect of RA on compressive strength was approximately similar up to 50% replacement of recycled aggregate. Beyond the 50% replacement of recycled aggregate, the reduction in compressive strength at 28 days was less significant than that at 7 days. This discrepancy effect between the compressive strength at 7 and 28 days can be attributed to the different contributions of recycled aggregate in the compressive strength. At the age of
7 days, the contribution of recycled aggregate is higher than that at 28 days because of the incomplete formation of cement hydration products. As the age of concrete increases, the contribution of the aggregate decreases. The recycled aggregate is expected to be weaker, in terms of compressive strength, than the natural aggregate.

### 3.2. Resistance of Concrete Having RA to Magnesium Sulfate Attack

Mass losses of the reference and modified mixtures having different levels of RA were recorded every week during the ten weeks of the partial immersion of concrete specimens in the three concentrations of magnesium sulfate solutions. Tables 5–7 depict the percentage of mass loss of concrete specimens of reference and modified mixtures immersed in 2.5%, 4.5%, and 6.5% magnesium sulfate solutions, respectively. The three tables clearly show that the mass loss proportionally increased with testing period and the replacement percentage of recycled aggregate. At the end of the 10-week testing period, mass losses of concrete specimens partially immersed in magnesium sulfate solution of 2.5% concentration were found to be 9.5%, 10.2%, 11%, 15.1%, and 17.2% for mixtures M0, M25, M50, M75, and M100, respectively. It can also be noticed that the mass loss of concrete specimens of the reference mixture partially immersed in 2.5%, 4.5%, and 6.5% magnesium sulfate solutions was 9.5%, 9.9%, and 12.2%, respectively, indicating that the relationship between the concentration of the magnesium sulfate solution and the mass loss is not linear. This nonlinear relation is also applicable for other mixtures having different replacement percentages of RA. The tables also reveal that the rate of mass losses of reference and modified mixtures was higher in the second half than that of the first half of the testing period.

Figure 3 shows concrete specimens that were immersed for only one week in sulfate magnesium solution having a concentration of 6.5%.

### Table 5: Mass loss percentages of concrete specimens partially immersed in a 2.5% magnesium sulfate solution of reference and modified mixtures.

| Testing date | M0  | M25 | M50 | M75 | M100 |
|--------------|-----|-----|-----|-----|------|
| 1<sup>st</sup> week | 0.20 | 0.20 | 0.20 | 0.21 | 0.22 |
| 2<sup>nd</sup> week | 0.57 | 0.59 | 0.61 | 0.82 | 0.85 |
| 3<sup>rd</sup> week | 1.20 | 1.39 | 1.42 | 2.00 | 2.10 |
| 4<sup>th</sup> week | 2.70 | 2.80 | 3.00 | 3.20 | 3.70 |
| 5<sup>th</sup> week | 4.00 | 4.20 | 4.40 | 4.70 | 5.10 |
| 6<sup>th</sup> week | 5.80 | 6.00 | 6.40 | 7.30 | 7.80 |
| 7<sup>th</sup> week | 6.90 | 7.20 | 7.60 | 9.00 | 10.00 |
| 8<sup>th</sup> week | 7.70 | 8.00 | 8.80 | 12.10 | 12.50 |
| 9<sup>th</sup> week | 8.60 | 9.20 | 10.00 | 13.80 | 14.70 |
| 10<sup>th</sup> week | 9.50 | 10.20 | 11.00 | 15.10 | 17.20 |

Figure 5 shows the relationship between the percentage of replacement of recycled aggregate and mass loss of concrete specimens at the termination of the test in magnesium sulfate solutions (2.5%, 4.5%, and 6.5%) for the reference and modified mixtures. It can be seen that the trend of the mass loss for reference and modified mixtures was approximately similar in the three different concentrations of magnesium sulfate solutions. In other words, the rate of the mass loss of the mixtures was approximately constant in the different concentrations of...
magnesium sulfate solutions considering that the absolute value of the mass loss was different. Nonetheless, the rate of the mass loss was somehow increased when the concentration of magnesium sulfate solution increased from 4.5% to 6.5% compared to the increase from 2.5% to 4.5%. This behavior of the mass loss was similar for all modified mixtures having different percentages of recycled aggregate.

The significant mass loss occurred in concrete specimens especially those partially immersed in the highest concentration of magnesium solution can be mainly attributed to more than one reason including

(i) Formation of gypsum and ettringite owing to the chemical reactions between the magnesium sulfate and hydration products. Both gypsum and ettringite have higher volume compared to the original materials which cause pressures that lead to spilling in concrete.

(ii) Crystallization of sulfate salts in concrete pores and cracks which generates additional pressure on concrete surface and results in falling of concrete paste.

(iii) Deterioration owing to the effect of dry/wetting cycles and its effect in exacerbating of the formation of gypsum and ettringite and the crystallization of sulfate salts. It should be stated that values of mass losses recorded in this investigation are significantly higher than those recorded in previous investigations performed without considering the effect of drying/wetting cycles [22].

3.3. Resistance of Concrete Having RA to Sodium Sulfate Attack. Three concrete specimens of each of reference and modified mixtures (total of fifteen specimens) were partially immersed for ten weeks in sodium sulfate solutions having concentrations of 2.5%, 4.5%, and 6.5%. Tables 8–10 depict the average mass loss of concrete specimens of each mixture at the end of every week of the ten-week partial immersion in concentrations of 2.5%, 4.5%, and 6.5% of sodium sulfate solutions, respectively. Table 8 shows that no mass loss occurred in the five mixtures at the end of the first week of the partial immersion in sodium sulfate of 2.5% concentration. The concrete specimens of M0 and M25 mixtures also exhibited no mass loss at the end of first week of partial immersion in sodium sulfate having a concentration of 4.5%. Otherwise, all the other concrete specimens of different mixtures exhibited mass loss owing to the partial immersion in sodium sulfate of various concentrations.

Mass losses of concrete specimens of the reference mixture were found to be 3.5%, 5.4%, and 6.23% at the end of the testing period owing to the attack of sodium sulfate solutions with concentrations of 2.5%, 4.5%, and 6.5%, respectively. These mass losses were increased by approximately 11%, 27%, and 54%, respectively, for concrete mixtures made with 100% replacement of recycled aggregate. In all the three concentrations of sodium sulfate solutions, the mass loss was directly proportional to the period of the partial immersion and the concentration of the sodium sulfate. It was observed that the trend of the mass loss during the testing period of the five mixtures was approximately similar.

The mass losses of the five concrete mixtures attacked by sodium sulfates were found to be less than those of the five mixtures attacked by magnesium sulfates. This can be attributed to the fact that the sodium sulfate is less aggressive, in terms of chemical reaction with hydration products, than the magnesium sulfate. It can be seen that mass losses of the different concrete mixtures attacked by sodium sulfates were about half of those of concrete mixtures attacked by magnesium sulfates.

The average mass losses of concrete specimens of the reference and those made with different percentages of recycled aggregate at the end of ten weeks of partial immersion in various concentrations of sodium sulfate solution are shown in Figure 6. Regardless the value of the mass loss, the rate of mass loss of different concrete mixtures partially immersed in sodium sulfate solution with a concentration of 2.5% was very comparable to that of concrete mixtures partially immersed in sodium sulfate solution with a concentration of 4.5. For concrete mixtures that were partially immersed in the sodium sulfate solution having a concentration of 6.5%, the rate of mass loss was significantly increased for concrete mixtures having more than 50% replacement of recycled aggregate.
The mass losses observed in the concrete specimens attacked by sodium sulfate solutions can also be attributed to the previously stated reasons considering that the rate of formation of gypsum and ettringite owing to sodium sulfate attack is less than that of magnesium sulfate attack.

### Table 8: Mass loss percentages of concrete specimens of reference and modified mixtures partially immersed in 2.5% sodium sulfate solution.

| Testing date | M0 | M25 | M50 | M75 | M100 |
|--------------|----|-----|-----|-----|------|
| 1st week     | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| 2nd week     | 0.21 | 0.21 | 0.25 | 0.27 | 0.40 |
| 3rd week     | 0.47 | 0.49 | 0.53 | 0.57 | 0.61 |
| 4th week     | 0.89 | 0.89 | 0.92 | 0.95 | 1.01 |
| 5th week     | 1.20 | 1.21 | 1.32 | 1.32 | 1.35 |
| 6th week     | 1.50 | 1.60 | 1.60 | 1.61 | 1.65 |
| 7th week     | 1.90 | 1.90 | 2.00 | 2.10 | 2.22 |
| 8th week     | 2.40 | 2.50 | 2.52 | 2.63 | 2.80 |
| 9th week     | 2.90 | 3.00 | 3.09 | 3.12 | 3.27 |
| 10th week    | 3.51 | 3.52 | 3.60 | 3.71 | 3.91 |

### Table 9: Mass loss percentages of concrete specimens of reference and modified mixtures partially immersed in 4.5% sodium sulfate solution.

| Testing date | M0 | M25 | M50 | M75 | M100 |
|--------------|----|-----|-----|-----|------|
| 1st week     | 0.00 | 0.00 | 0.09 | 0.11 | 0.17 |
| 2nd week     | 0.31 | 0.41 | 0.50 | 0.67 | 0.69 |
| 3rd week     | 0.59 | 0.61 | 0.79 | 0.85 | 0.92 |
| 4th week     | 1.32 | 1.42 | 1.43 | 1.47 | 1.52 |
| 5th week     | 2.10 | 2.18 | 2.22 | 2.31 | 2.43 |
| 6th week     | 2.41 | 2.51 | 2.57 | 2.61 | 2.89 |
| 7th week     | 2.89 | 3.12 | 3.37 | 3.51 | 3.79 |
| 8th week     | 3.55 | 3.67 | 4.01 | 4.11 | 4.29 |
| 9th week     | 4.20 | 4.46 | 4.81 | 5.09 | 5.21 |
| 10th week    | 5.40 | 5.70 | 6.01 | 6.32 | 6.89 |

### Table 10: Mass loss percentages of concrete specimens of reference and modified mixtures partially immersed in 6.5% sodium sulfate solution.

| Testing date | M0 | M25 | M50 | M75 | M100 |
|--------------|----|-----|-----|-----|------|
| 1st week     | 0.09 | 0.09 | 0.11 | 0.18 | 0.23 |
| 2nd week     | 0.41 | 0.42 | 0.59 | 0.99 | 1.31 |
| 3rd week     | 1.28 | 1.31 | 1.47 | 1.82 | 2.22 |
| 4th week     | 2.01 | 2.17 | 2.37 | 3.21 | 3.43 |
| 5th week     | 3.45 | 3.52 | 3.72 | 4.01 | 4.32 |
| 6th week     | 3.92 | 3.95 | 4.01 | 5.12 | 5.49 |
| 7th week     | 4.51 | 4.61 | 4.92 | 5.92 | 6.71 |
| 8th week     | 5.20 | 5.30 | 5.78 | 6.57 | 7.42 |
| 9th week     | 5.62 | 5.72 | 6.39 | 7.21 | 8.11 |
| 10th week    | 6.23 | 6.37 | 7.21 | 8.11 | 9.60 |

### Figure 6: Mass losses of concrete specimens of reference and modified mixtures at the end of 10 weeks of partial immersion in various concentration of sodium sulfate solution.

$$y = 1.9736x + 0.8849$$

$$R^2 = 0.9374$$

### Figure 7: Relationship between mass loss and reduction in compressive strength of 90 concrete specimens that were partially immersed in various concentrations of magnesium and sodium sulfate solutions.

in various concentrations of sodium and magnesium sulfate solutions was measured at the end of the testing period (ten weeks). Figure 7 shows the relationship between mass losses of the ninety concrete specimens (three specimens of each mixture in each concentration) at the end of testing period and the reduction in compressive strength owing to the attack of various concentrations of sodium and magnesium sulfate solutions. The figure clearly shows that the reduction in compressive strength increased as the mass loss increased. This directly proportional relationship can be attributed to the fact that higher mass loss, which means more loss in cement paste and more destruction in structural integrity

### 3.4. Reduction of Compressive Strength. The compressive strength of concrete specimens that were partially immersed
and damage of concrete matrix, results in more reduction in the compressive strength.

A regression analysis was performed on data of Figure 7 and results showed a linear trend with an $R^2$ value of 0.937. The linear trend suggests that the rate of reduction in the compressive strength is approximately 2 times the mass loss. In other words, each 1% mass loss causes approximately 2% reduction in the compressive strength of concrete.

4. Conclusions

This study investigated the effect of sodium and magnesium sulfate attack of various concentrations on recycled aggregate concrete subjected to dry-wetting cycles. Based on results presented in this paper, the following conclusions can be drawn:

1. Using recycled aggregate as a replacement of the natural coarse aggregate decreased the compressive strength of concrete at ages of 7 and 28 days. The decline in the compressive strength was directly proportional to the percentage of the replacement. The reduction in the compressive strength was higher at age of 7 days than that at age of 28 days.

2. Mass losses owing to the partial immersion of concrete specimens, made with different percentages of recycled aggregate, in various concentrations of magnesium sulfate solutions were increased as the percentage of recycled aggregate increased and as the concentration of the magnesium sulfate increased.

3. Although concrete specimens having various percentages of recycled aggregate did not exhibit any mass losses during the first week of the partial immersion in various concentrations of sodium sulfate solutions, it was found that the mass loss increased as the concentration of the sodium sulfate and the replacement percentage of recycled aggregate increased.

4. Mass losses of concrete specimens of the reference and modified mixtures attacked by various concentrations of sodium sulfates were approximately half of those attacked by the same concentrations of magnesium sulfates. It should be noted that mass losses recorded in this study involved the combined effect of the sulfate attack and the drying-wetting effect. Therefore, results of this investigation should be interpreted within this context.

5. For all concrete specimens of reference and modified mixtures attacked by various concentrations of sulfates, the relationship between the reduction in compressive strengths and mass losses was found to follow a linear trend ($R^2 = 0.937$) with a slope of approximately 2, suggesting that the percentile reduction in compressive strength is equal to 2 times the percentile of the mass loss.

Data Availability

The data used to support the findings of the study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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