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Comparative Analysis of Ammonium Nitrate and Water Exposure on Polymer Resin Concrete vs. Traditional Concrete

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Abstract

The research examines the effect of ammonium nitrate and water exposure on the mechanical characteristics of polymer resin-coated concrete compared to traditional concrete. The study investigates the basics like compressive strength, tensile strength, and flexural strength over 28, 56, and 90 days. The preliminary outcomes of the study revealed that polymer resin-coated concrete showed increased mechanical characteristics, specifically in the beginning when compared with high-strength concrete to traditional concrete. With time, the protective impact of polymer resin decreases, causing a decline in compressive strength and tensile strength at the 90-day mark, pertinent to under-aggressive chemical exposure. The stability and consistent performance of traditional concrete increased when passed through water curing processes i.e. 28 to 90 days. It is found that compressive strength, tensile strength and flexural strength an increasing percentage for polymer resin-coated concrete: 22.88%, 26.31%, and 34.34%, respectively tested at 28 days of exposure. However, at 56 days, the increase in age for polymer-coated concrete is recorded as compressive strength at 30.4%, tensile strength at 50.7%, and flexural strength at 59.1% as compared to strength of traditional concrete tested at same days of curing. Similarly, the percentage increase in polymer-coated concrete when exposed to ammonium nitrate for 90 days in compressive, tensile, and flexural strength is 29.64%, 25.66%, and 36.8%, respectively. The positive performance observed and introduced the concrete an effective material for long term usage and to offset the impact of harsh environment. Hence, the comparison of traditional vs polymer resin-coated concretes under environment of two substances present that concretes' stability and good performance is associated with the use of right substance coating and the extent of aggressiveness of the environmental conditions.

Keywords: Polymer resin, traditional concrete, ammonium nitrate, water exposure, compressive strength, tensile strength, flexural strength

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1. Introduction

The preliminary function of concrete in buildings is the development of stable foundation in buildings of different categories like residential buildings and the large scale industrial projects [1]. The composition of mixture of cement and aggregates (sand, gravel and water) performs well when involved the mechanical versatility and uniqueness of the techniques. However, the engagement of chemical reaction can improve the strength and hardness of the mixture [2]. The most important consideration in this case is the choice of cement and the type of aggregates of mixture to enhance the characteristics like strength, stability and consistency [1]. Despite the proposed strength, concrete shows vulnerability to chemical reactions pertinent to exposure of substances like ammonium nitrate and in common cases water [3].

For example, the industrial setting selected for this study is Fatima Fertilizers Company Ltd (FFCL) located in Sadiq Abad. The building material used in this premises comprised of ammonium nitrate and water coated concrete. The building material induces structural integrity and environmental complexity risks for the premises. The degradation is however, seemed intensified with corrosion of steel and issue of production of ammonia gas as the bye-product of chemical exposition.

The main objective of the research is to find out the challenges of durability, consistency and strength of concrete when decided to compare the performance of traditional concrete and polymer resin-coated concrete. The performance comparison is to be examined in ammonium nitrate and water-controlled environments. Another objective of this study is to investigate the durability and longevity of concrete and its contribution to sustainable infrastructure plus innovation. Moreover, the critical assessment of the impact of water on polymer resin-coated concrete versus traditional concrete is the following research objective. The research seeks long-term visibility of polymer coatings and their effectiveness while analyzing changes in chemical properties over 28m, 56, and 90 days.

2. Materials and Methods

2.1. Materials Used in Research

The usage of variety of material in this study leading to the evaluation of the effect of ammonium nitrate and water on two concrete structures imposes versatility and uniqueness. The selection of coarse aggregates for the evaluation of relationship between angular shapes and strength & stability of concrete [4] made the study interesting and informative. The consideration of fine aggregates remained effective to find out cavities and cohesiveness property of concrete [5]. ASTM C150/C150M standards and OPC (ordinary Portland cement) are planned to follow up and to better understand the core characteristics of concrete's strength, durability and consistency [6]. Application of Polyurethane gave extra protection to concrete and increased its stability along with improvement in waterproof ability. The material also showed resistance to damages due to chemical reactivity and abrasion [7]. We used material plane to evaluate adhesive properties and appropriateness of mixture usage in buildings and the resultant stiffness and flexibility when exposed to different weather conditions [8].

2.2. Testing Material

The research focuses on the investigation of the impact of ammonium nitrate and water exposure on traditional concrete and polymer resin-coated concretes. This research relies heavily on local resources and uses 19 mm Sargodha Crush for coarse aggregate, river sand for fine aggregate and Maple of Leaf Ordinary Portland Cement (OPC) as binder. The phenomenal issues like enhance chemical resistance and protection against water induced degradation [9] observed in this study through use of polymer resin-coated concrete. The proposed material is to be examined for its adhesion and flexibility. It is also examined the impact of sustainability and concrete performance when exposed to chemical processes [10]. Another point of examination in this study is the finding of insights in the reduced damages of polymer resin coated concrete as compared to traditional concrete.

2.3. Specimen Preparation

The specimen is prepared with cubes, cylinders, and prisms to assess the compressive, tensile, and flexural strengths. Surface treatment is used to examine the impact of water on Polymer Resin Concrete versus Traditional Concrete. For this purpose, half of the specimen are coated with Polymer Resin, and the rest of the specimen are left uncoated. In this study, ammonium nitrate and water curing are initially used for specimen testing, and the specimen is exposed to ammonium nitrate and water solution for 28, 56, and 90 days, respectively. The technique reinforces the stimulation of an aggressive chemical environment, permitting the evaluation of the performance of polymer-coated versus uncoated concrete, resistant to chemical reaction for the selected time.

2.4. Testing Procedures

To examine the impact of the selection of testing procedures following the ASTM standards. For this purpose, the specified test was performed to assess the strength of cubes, splitting tensile strength of cylinders, and flexural strength of prisms. The recorded results and analysis investigated the impact of ammonium nitrate and water on both polymer resin-coated and traditional concrete. However, to reinforce the concepts, the following testing methods were used for the evaluation of the degradation of concrete samples:

- **Compressive Strength Test (BS EN 12390-3)**: Through this test, the researchers can measure the maximum compressive force the concrete sample can bear [11]. During this test, the simple cubes and cubes that are coated exposed to water to start the chemical process for more curing. Gradual increasing load is being applied during the testing till the cube fails. Reaching the failure point, the load indicates the compressive strength of the cube. The change in compressive strength of both concretes is shown in **Fig 1.**

Figure 1. compression test according to ASTM (BS EN 12390-3)

- **Splitting Tensile Strength Test (ASTM C496)**: This test enables the researcher to examine the tensile strength and the sample's resistance capacity to tension-induced failure [12]. This testing process involves preparing and curing concrete cubes while they are coated with polymer resin as shown in **Fig 2**.

Figure 2. Splitting Tensile Strength Test of Specimens (ASTM C496)

After exposure to water, the researcher can measure the tensile strength through the splitting tensile method. In this method, the researcher can apply the compressive load until the cube is split and analyze the results to compare the effectiveness of the polymer resin coating to protect the concrete from chemical degradation, evaluating its strength on tensile strength and durability. Fig 3 and Fig 4 show the tensile strength of polymer resin concrete and traditional concrete when exposed to water. The change in compressive strength of concretes when exposed to ammonium nitrate as shown in **Fig 4.**

Figure 3. Molar solution of Ammonium nitrate 1:1.25

- **Flexural Strength Test (ASTM C78)**: The researcher can assess the concrete's ability to resist bending or flexural stress [13] as shown in **Fig 4**. Polymer resin-coated concrete resists chemical attacks better, but with time, the protective layer reduces, resulting in a decline in strength. On the other hand, traditional concrete is susceptible to damage and a gradual decline in strength.

Figure 4. Flexural Strength of Beams (ASTM C 78)

2.5. Data Collection and Analysis

Tests conducted during the study are solely based on ASTM standards, ensuring accuracy and reliability. However, the tests accurately assess the mechanical properties of polymer resin-coated and traditional uncoated concrete. Once the initial cure is completed, the researcher exposes the specimen to a water solution for 28, 56, and 90 days. The data of these tests were recorded and analyzed meticulously to examine the impact of water exposure on the structural integrity of the selected concretes. The results, however, determine the relative performance of polymer resin concrete and traditional concrete in an environment that resists water-induced degradation. The following analysis provides a detailed assessment of the performance differences between Polymer Resin Concrete and Traditional Concrete. The following analysis will give an insightful examination of polymer coating’s effectiveness in increasing the durability of concrete in a chemically aggressive environment.

3. Results

3.1. Compressive Strength

As shown in **Table 1.** The compressive strength of traditional concrete increases gradually and reaches 32.9 MPa overtime on the 90th day when exposed to water. However, the compressive strength of polymer resin-coated concrete, presents compressive strength on the 28th and 56th day, i.e., 18.9 and 20.25, respectively. However, a slight decline was observed on day 90th, i.e. 19.73 MPa. It is an indication of the reduced effectiveness of polymer coating over time. The results significantly show that water changes surface properties while affecting the strength, which helps assess the performance of concrete in an aggressive chemical environment.

Table 1. Compressive strength of different specimens for 28, 56, and 90 days

Sr No	No of days at testing	Normal concrete cured in water (MPa)	Normal concrete cured in ammonia (MPa)	Polymer coated concrete (MPa)
1	28	22.63	15.38	18.9
2	56	27.25	15.53	20.25
3	90	32.9	16.49	19.73

3.2. Tensile Strength

Table 2 shows a consistent trend in the tensile strength of traditional concrete. A slight change in tensile strength was observed when the concrete was exposed to water for 28, 56, and 90 days. For instance, tensile strength initially declined from 2.14 MPa on the 28th day to 2.56 MPa on the 56th day. However, the rise in tensile strength of concrete, i.e., 3.44 in 90 days, shows good material properties recovery over prolonged water exposure. In contrary **Table 2** shows the tensile strength of polymer-coated concrete cylinders after 28, 56, and 90 days of chemical degradation. For each period, three specimens tested showed an increase from 1.92 MPa in 28 days to 2.11 MPS in 56 days, but a slight decline to 2.00 MPa was observed at 90 days.

Table 2. Splitting tensile strength of Different specimens for 28, 56, and 90 days

Sr No	No of days at testing	Normal concrete cured in water (MPa)	Normal concrete cured in ammonia (MPa)	Polymer coated concrete (MPa)
1	28	2.14	1.52	1.92
2	56	2.56	1.40	2.11
3	90	3.44	1.66	2.00

3.3. Flexural Strength

Similar trends were observed in flexural strength tests. When traditional concrete is exposed to water, a simple and stable increase in strength is seen, i.e., 6.21 MPa at 90 days, extended from 5.54 at 56 days and 4.27 at 28 days, as shown in **Table 3**. On the other hand, exposure to water polymer concrete shows a more robust observation of 3.99 MPa at 28 days, which shows a gradual decline from 4.97 MPa at 56 days to 4.87 MPa at 90 days.

Table 3. Flexural strength of Different specimens for 28, 56, and 90 days

Sr No	No of days at testing	Normal concrete cured in water (MPa)	Normal concrete cured in ammonia (MPa)	Polymer coated concrete (MPa)
1	28	4.27	3.99	2.97
2	56	5.54	4.97	3.124
3	90	6.21	4.87	3.23

4. Comparison of Strength: Traditional Concrete vs. Polymer Resin-Coated Concrete Exposed to Ammonium Nitrate

a) Comparison at 28 Days b/w polymer-coated concrete and Traditional Concrete exposed to Ammonium nitrate.

Table 4 shows that when purposed concrete is affected by ammonium nitrate, it is compared with normal concrete that is dipped in ammonium nitrate solution for 28 days. The compressive, tensile, and flexural strengths for traditional and polymer-coated concrete were recorded as 15.38MPa, 1.52MPa, 2.97MPa, 18.92MPa, 1.92MPa, and 3.99 MPa, respectively. We found an increasing percentage for polymer resin-coated concrete: 22.88%, 26.31%, and 34.34%, respectively.

Table 4. Comparison at 28 Days b/w Polymer Coated concrete and Traditional Concrete exposed to Ammonium nitrate.

Sr. No	Tests	Simple Specimens Exposed to ammonia (MPa)	Polymer coated Specimens exposed to ammonia (MPa)	%age Increase of Polymer concrete (MPa)
1	Compressive strength (MPa)	15.38	18.9	22.88%
2	Splitting Tensile strength (MPa)	1.52	1.92	26.31 %
3	Flexural strength (MPa)	2.97	3.99	34.34 %

b) Comparison at 56 Days b/w polymer-coated concrete and Traditional Concrete exposed to Ammonium nitrate.

Table 5 shows that when traditional concrete and Polymer concrete were treated with an ammonium nitrate solution for 56 days, their compressive, tensile, and flexural strengths were 15.53 MPa, 1.40 MPa, and 3.124 MPa and 20.25 MPa, 2.11MPA, and 4.97 MPa, respectively. However, the increase in age for polymer-coated concrete is recorded as compressive strength at 30.4%, tensile strength at 50.7%, and flexural strength at 59.1%.

Table 5. Comparison at 56 Days b/w Polymer Coated concrete and Traditional Concrete exposed to Ammonia

Sr. No	Tests	Simple Specimens exposed to ammonia	Polymer coated Specimens	%age Increase of Polymer concrete
1	Compressive strength (MPa)	15.53	20.25	30.4 %
2	Splitting Tensile strength (MPa)	1.40	2.11	50.7 %
3	Flexural strength (MPa)	3.124	4.97	59.1 %

c) Comparison at 90 Days b/w polymer-coated concrete and Traditional Concrete exposed to Ammonium nitrate.

Table 6 shows that after 90 days of testing, traditional and polymer-coated concrete improved their compressive, tensile, and flexural strengths by 16.49MPa, 1.66MPa, 3.23MPa, 19.73MPa, 1.92MPa, and 4.87MPa, respectively. The percentage increase in polymer-coated concrete when exposed to ammonium nitrate for compressive, tensile, and flexural strength is 29.64%, 25.66%, and 36.8%, respectively.

Table 6 Comparison at 90 Days b/w Polymer Coated concrete and Traditional Concrete exposed to Ammonium nitrate.

Sr. No	Tests	Simple Specimens exposed to ammonia	Polymer coated Specimens	%age Increase of Polymer concrete
1	Compressive strength (MPa)	16.49	19.73	29.64 %
2	Splitting Tensile strength (MPa)	1.66	1.92	25.66 %
3	Flexural strength (MPa)	3.23	4.87	36.8 %

5. Discussion

This study conducts a comparative analysis to see the impact of water exposure on polymer resin-coated concrete versus traditional concrete. The experimental process is based on compressive, tensile, and flexural strengths over 28, 56, and 90 days. The research findings show distinct performance traits of these two concrete under prolonged water exposure. The experiment also presents the concrete's durability and structural integrity, respectively.

a) Compressive Strength

The experiment results for compressive strength reveal a significant contrast between traditional concrete and polymer resin-coated concrete. Traditional concrete presents a gradual and consistent increase in compressive strength over time, reaching 32.9 MPa on the 90th day of exposure. This positive trend suggests that traditional concrete is beneficial when exposed to water for a prolonged period. This exposure can increase its strength by undergoing a process of hydration. In this exposure, water reacts as a catalyst in the hydration reaction of cement and can contribute to the gradual development of a dense microstructure and ultimate high compressive strength.

On the other hand, polymer resin-coated concrete presented a different state. In the beginning, the compressive strength of the polymer-coated concrete when exposed to water was less than that of traditional concrete, showing values of 18.9MPa on the 28th day and 20.25 MPa on the 56th day. Irrespective of the increase in strength on the 56th day, the concrete shows a reverse process, and results are slightly less on the 90th day of exposure, i.e., 19.73 MPa. The decline in strength presents that polymer resin-coated concrete can give some protective benefits, but its effectiveness diminishes with time when exposed to water. Polymer resin impedes the natural hydration process or may deteriorate after long-term exposure to water. This exposure caused a reduction in the strength of polymer resin-coated concrete. The outcome shows the significance of evaluating the long-term performance of polymer coating specific to the environment of consistent exposure to water.

The comparison of traditional concrete and polymer-coated concrete when exposed to ammonium nitrate shows different results, and we find an increase in the strength of polymer-coated concrete. For instance, at the 28-day comparison, the results of traditional concrete for compressive strengths were 15.38MPa for polymer-coated concrete and 18.9MPa, respectively. Similarly, the results for compressive strength at 56-day comparisons were 15.53MPa (traditional concrete) and 2.11MPa (polymer-coated concrete), respectively. At 90-day comparison, the compressive strength of traditional and polymer-coated concrete was observed as 16.49MPa and 19.73MPa, respectively. Hence, polymer-coated concrete exposed to ammonium nitrate shows positive results in terms of durability and sustainability even when exposed to harsh environments.

b) **Tensile Strength**

When exposed to water, the tensile strength outcome presents the different performances of traditional and polymer resin-coated concrete. Traditional concrete constantly increases tensile strength for the period selected for this research work. The outcome of traditional concrete strength when exposed to water presents an increasing trend in strength, e.g. 2.14 MPa at the 28th day, 2.56 MPa at the 56th day, and 3.44 MPa at 90 days. This rising trend in strength after being exposed to water indicates the beneficial effect of water curing with the likelihood of improvement in the bonding between the cement matrix and the aggregate following to increase in tensile strength. In contrast to traditional concrete, the polymer resin-coated concrete presented a different trend. Despite the initial increase in tensile strength from 1.92 MPa on the 28th day to 2.11 MPa on the 56th day, a slight reduction in the strength is seen on the 90th day. It dropped to 2.00MPa on the 90th day, and this reduction proposes a negative impact of water curing over polymer resin-coated concrete. The declining trend in tensile strength of polymer resin-coated concrete after water curing is similar to compressing strength results. The effectiveness of polymer resin-coated concrete decreases, and diminishing strength presents a negative impact of water curing on it for a prolonged time. The polymer coating may be a good protector from moisture ingress. However, after long-term exposure to water, the breakdown of the coating happens to cause micro-cracks and reduces the tensile strength of polymer concrete. The comparison of traditional concrete and polymer-coated concrete when exposed to ammonium nitrate shows different results, and we find an increase in the strength of polymer-coated concrete. For instance, in the 28-day comparison, the results for traditional concrete for tensile strength were 1.52MPa, and for polymer-coated concrete, they were observed as 1.92MPa, respectively. Similarly, at 56 days of comparison, the results for the tensile strength of traditional and polymer-coated concrete were 1.40 MPa and 2.1MPa, respectively. At 90-day comparison, the results were even more astonishing, i.e., 1.66 MPa for traditional concrete and

4.87MPa for polymer-coated concrete, depicting a positive performance trend of polymer-coated concrete in harsh environments.

c) Flexural Strength

The flexural strength indicated a consistent increase in the strength of traditional concrete when served water curing. The flexural strength increased gradually from 4.27 MPa on the 28th day to 5.54 MPa on the 56th day to 6.21 MPa on the 90th day. This outcome shows that traditional concrete gains strength when exposed to water and can resist bending processes. The continuation of the hydration process contributes to developing a cohesive and resilient concrete matrix while increasing the flexural strength.

On the other hand, the polymer resin-coated outcome shows an increase in flexural strength at the beginning of the process, i.e., 3.99MPa on the 28th day and 4.97MPa on the 56th day, but a slight decline of 4.87MPa on the 90th day. The reduction in flexural strength shows that polymer resin-coated concrete cannot maintain flexural strength over time when exposed to water. The coating prevents optimum hydration and causes degradation with exposure to water following a decline in flexural strength.

The comparison of traditional concrete and polymer-coated concrete when exposed to ammonium nitrate shows different results, and we find an increase in the strength of polymer-coated concrete. For instance, at the 28-day comparison, the results of traditional concrete for flexural strengths were 2.97MPa, and flexural strength for polymer-coated concrete was 3.99MPa, respectively. The flexural strength of traditional and polymer-coated concrete on the 56th day was recorded as 3.12 MPa and 4.97MPa, respectively. However, the flexural strength of traditional and polymer-coated concrete on the 90th day was recorded as 3.23 MPa and 4.87MPa, respectively.

6. Conclusion

- Consistent progress in mechanical characteristics observed in traditional concrete when exposed to water. This is because of the consistent and long term exposure to hydration process.
- However, the impact of exposure to ammonium nitrate produced positive results and improves the over-all performance of polymer resin-coated concrete. But the long term exposure to polymer resin-coated concrete to water remained ineffective as diminished properties observed to cause potential decline in strength of concrete.

- The research led the engineers to make correct decisions at the time of considering material mixture for long term efficient function and to improve the deteriorating impact of environment on concrete . Hence, the comparative analysis reinforces the idea that water curing is beneficial for tradition concretes and can improve its strength and reliability when exposed for a long term.
- On the other ammonium nitrate exposure can enhance the mechanical properties of polymer coated concrete when exposed to chemical for an appropriate period.

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