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Experimental Investigation on Durability Performance of Nano Orion–Modified M35 Grade Concrete

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Abstract –

Concrete structures exposed to harsh conditions like sulphates, acids, and chlorides often deteriorate faster, decreasing their lifespan and raising maintenance expenses. Improving concrete durability while supporting sustainable building practices has become a key research area. This study examined the effectiveness of Nano Orion, a nano-silica–based material, as a partial cement substitute in M35 concrete. Nano Orion was added at replacement levels of 0%, 1%, 2%, 3%, 4%, and 5% by weight of cement, with a constant water–binder ratio. Durability was tested through sulphate attack, acid resistance, and chloride resistance, measuring weight loss and residual compressive strength. Results showed significant durability improvements with Nano Orion compared to standard concrete. The mix with 3% Nano Orion performed best overall, showing minimal mass loss and strength reduction under harsh conditions. The durability boost is due to Nano Orion's pozzolanic activity and fine filler properties, which refine pores, densify the matrix, and generate more secondary C–S–H gel. Levels above 3% slightly decreased performance, likely from nanoparticle agglomeration and dispersion issues. Overall, 3% Nano Orion is identified as the optimal amount for enhancing M35 concrete's durability. The results suggest Nano Orion–modified concrete can be a durable, sustainable material for structures in aggressive environments.

Key Words: Nano Orion; Nano-silica; M35 grade concrete; Durability performance; Sulphate resistance; Acid resistance; Chloride resistance; Sustainable concrete

1. INTRODUCTION

It's no secret that for over a century, concrete has been the undisputed champion of building materials worldwide. This is mainly because it's incredibly flexible, doesn't break the bank, and works for almost any project you can think of. At its core, it's just a simple recipe of cement, sand, gravel, and water that hardens into a rock-solid mass, perfect for handling heavy loads. Consider our modern world—the buildings, bridges, dams, and highways all rely on concrete's strength and durability. It outperforms materials like wood and steel because it doesn't burn, withstands harsh weather, and requires minimal maintenance, making it a top choice in construction. But for all its strengths, concrete isn't perfect. It has some known weaknesses, like not handling being pulled apart very well (that's its tensile strength), letting water soak in, and a tendency to crack and shrink. These issues can significantly reduce a structure's lifespan, especially in harsh environments. And that's a real issue today, as we try to build things that last and are suitable for the planet. There are also chemical helpers, such as superplasticisers, that make fresh concrete easier to work with or even stronger. However, even with these upgrades, the old problems of tiny cracks and water infiltration didn't entirely disappear. That's when Nanotechnology entered the scene and completely changed the game. It's all about tinkering with materials at the tiniest possible level—the Nanoscale—to give them superpowers. For concrete, this means improving hardening, densifying the internal structure, and increasing the amount of C-S-H gel, which serves as the binding agent that gives concrete its strength and durability.

Super-small materials, such as Nano-silica, Nano Titania, and carbon Nanotubes, have already yielded some remarkable results in enhancing the strength and resilience of concrete. Nano-silica, in particular, has been a key player in research. It works in two ways: it acts as a super-fine filler to seal microscopic pores, and it triggers a chemical reaction that strengthens the bond between the cement paste and the gravel. It essentially replaces a weak by-product of the concrete-making process with more of the powerful C-S-H "glue," which enhances the entire material. Additionally, these Nanoparticles significantly improve the concrete's resistance to substances such as salt, sulphates, and acids, making it ideal for structures located near the ocean or in industrial zones.

Using Nanomaterials, such as those from Nano Orion, also aligns with the construction industry's sustainability goals. Since you only need to add a small amount (usually replacing 1–5% of the cement), you can create concrete that's much stronger and more durable without using a ton of cement.

2. NANO ORION:

Developing new materials that are stronger, more functional, and longer-lasting remains a significant challenge for researchers. Scientists and tech enthusiasts are particularly interested in Nanomaterials at the moment because they can be utilised for a wide range of applications. Thanks to their incredible strength, superior chemical properties, and large surface area, these Nanostructured materials are becoming increasingly important.

Nano Orion is a unique, specially designed material made from Nano-silica that's generating a lot of buzz for improving the performance of cement and concrete. Nanomaterials, such as Nano Orion, have incredibly tiny particles (between 1 and 100 Nanometers), which give them a massive surface area and make them significantly more reactive than their normal-sized counterparts. Nano Orion is primarily composed of superfine silicon dioxide (SiO_2). These tiny particles work in two ways: as a reactive "pozzolanic" material and as a filler. The pozzolanic reaction eliminates a weak byproduct that forms when concrete hardens and replaces it with more of the strong "glue" (C-S-H gel) that gives concrete its strength. At the same time, the filler effect helps pack the space between the cement

paste and the gravel, making the concrete denser and less porous.

2.1. Advantages of Nano Orion

- **Makes It Stronger –** Nano Orion boosts all kinds of strength in concrete because of its special chemical reaction and how it fills in tiny gaps.
- **Improves the Internal Structure –** It tightens up the bond between the cement paste and the gravel, making the whole mix denser and more uniform.
- **Boosts Durability –** It makes the concrete less porous and less likely to absorb water, which helps it stand up to damage from carbonation, salt, sulfates, and acid.
- **Hardens Faster –** It gives the hardening reaction more places to start, which helps the concrete gain strength much quicker.
- **Good for Sustainability –** You can hit your target strength with less cement, which helps lower the CO_2 emissions that come from making cement.
- **Reduces Shrinking and Cracking –** The tiny particles fill in voids and cut down on micro-cracking, which helps the structure last longer.
- **Longer Service Life –** By preventing rust and other durability problems, Nano Orion helps concrete structures have a longer and more durable life.

2.2. Disadvantages of Nano Orion

- **Dispersion Issues –** Due to their excellent size, Nanoparticles tend to agglomerate if not properly dispersed, reducing their effectiveness in concrete mixes.
- **Workability Reduction –** Nano Orion has a very high surface area that increases water demand, often leading to reduced workability unless superplasticizers are used.
- **Health and Safety Concerns –** Nanoparticles are wonderful powders that can be hazardous if inhaled, requiring protective measures during handling and mixing.
- **Limited Large-Scale Research –** While laboratory studies have shown positive effects, long-term field data and practical implementation in large projects are still limited.
- **Mix Design Sensitivity –** The optimum dosage of Nano Orion is critical; overdosing can lead to excessive heat of hydration, shrinkage, or reduction in strength.
- **Compatibility Issues –** May show variable performance depending on cement type, admixtures, and aggregate properties, requiring careful mix design trials.

3. OBJECTIVES OF RESEARCH WORK:

The primary objective of the present investigation is to evaluate the effectiveness of Nano Orion as a partial replacement of cement in enhancing the durability performance of M35 grade concrete. The specific objectives of the study are as follows.

To design M35 grade concrete mixes incorporating varying percentages of Nano Orion (0%, 1%, 2%, 3%, 4%, and 5%) as a partial replacement of cement

- To assess the resistance of Nano Orion–modified concrete against sulphate attack by evaluating weight loss and compressive strength loss.
- To assess the acid resistance of concrete mixes containing Nano Orion through measurements of mass loss and residual compressive strength after acid exposure.
- To examine the chloride resistance of Nano Orion–based concrete by studying weight variation and strength degradation due to chloride ingress.
- To identify the optimum percentage of Nano Orion that provides maximum durability enhancement without adversely affecting concrete performance.

4. MATERIALS:

- *Cement:* We used a standard Ordinary Portland Cement (OPC) 43 grade, which meets the official IS: 8112-1989 standards.
- *Fine Aggregate:* This was clean river sand, which is pretty fine (classified as Zone IV), with a specific gravity of 2.60.
- *Coarse Aggregate*: For this, we used crushed angular stones that were 20 mm in size and had a specific gravity of 2.63.
- *Nano-Orino*: This is the special stuff. It's a super-pure Nano-silica with particles smaller than 100 nm. We used it to replace a small percentage of the cement, trying out different amounts (0%, 1%, 2%, 3%, 4%, and 5%).

5. METHODOLOGY:

The experimental program used M35 grade concrete following IS: 10262–2019 guidelines. It incorporated Ordinary Portland Cement (OPC) 43 grade, natural river sand as fine aggregate, and crushed coarse aggregate up to 20 mm in size. Nano Orion, a nano-silica–based material, was added as a partial cement replacement at 0%, 1%, 2%, 3%, 4%, and 5% by weight, with the water–binder ratio kept constant. Concrete specimens were cast, compacted, and cured under standard conditions. Durability was tested through sulphate attack, acid resistance, and chloride resistance by immersing specimens in chemical solutions. Deterioration was measured by weight loss and residual compressive strength. The performance of Nano Orion–modified mixes was compared to conventional concrete to identify the optimal replacement level**.**

6. MIX DESIGN;

We designed the M35 grade concrete mix in accordance with IS: 10262-2019. For all the different batches we made, we maintained the same water-to-cement ratio and aggregate amount. The only thing we changed was the Nano-Orino percentage, which we added to replace some of the cement's weight.

Table 1: Mix design of M35 with Nano Orion

Mix ID	Nano Orion (%)	Cement (kg)	Nano Orion (kg)	Water (kg)	FA (kg)	CA (kg)	SP (kg) *	w/b
0	**0**	**400**	**0**	**160**	**700**	**1200**	**4.0**	**0.40**
1	1	396	4	160	700	1200	4.8	0.40
2	2	392	8	160	700	1200	4.8	0.40
3	3	388	12	160	700	1200	4.8	0.40
4	4	384	16	160	700	1200	4.8	0.40
5	5	380	20	160	700	120	4.8	0.4

	0	0

7. RESULTS:

7.1. Sulphate Attack Test

In this research, a sulphate attack test was also conducted to assess how well the concrete would withstand areas with high sulphate levels, such as in certain soils or groundwater. The main problem is that when sulphate ions enter concrete, they react with the chemicals in the cement to form new compounds that expand. This expansion is what causes the concrete to crack, weaken, and fall apart. To see how well Nano Orion could prevent this, we submerged our concrete samples—each with a different percentage of it—in a sulphate solution. Afterwards, we measured the amount of weight and strength they had lost. This provided us with a clear understanding of the damage and demonstrated Nano Orion's effectiveness in enhancing concrete's resistance to this type of attack. Table 2 represents the Sulphate attack test of M35 concrete mix with Nano-Orion on Weight Loss and strength loss.

Table 2: Sulphate attack test of M35 concrete mix with Nano-Orion on Weight loss and Strength Loss

Nano Orion (%)	Initial Weight (g)	Final Weight (g)	Weight Loss (g)	% Weight Loss
Control (0%)	8100.0	8002.8	97.2	1.20%
1%	8100.0	8019.0	81.0	1.00%
2%	8100.0	8035.2	64.8	0.80%
3%	8100.0	8067.6	32.4	0.40%
4%	8100.0	8051.4	48.6	0.60%
5%	8100.0	8027.1	72.9	0.90%
Nano Orion (%)	**Original Strength (MPa)**	**Post-Attack Strength (MPa)**	**Strength Loss (MPa)**	**% Strength Loss**
Control (0%)	44.60	39.25	5.35	12.0%
1%	48.50	44.13	4.37	9.0%
2%	50.80	47.24	3.56	7.0%
3%	52.60	50.50	2.10	4.0%
4%	51.90	48.79	3.11	6.0%
5%	50.20	46.18	4.02	8.0%

From Table 2, two main aspects were examined to assess how well the concrete performed: the amount of weight it lost and the degree of weakening it experienced after exposure. To determine weight loss, we compared the samples' weights before and after the test. For strength, we measured the change in compressive strength from its original state to its state after exposure. The regular concrete mix (with 0% Nano Orion) took the biggest hit. It exhibited a noticeable mass loss, and its compressive strength decreased by approximately 12%, clearly demonstrating the vulnerability of regular concrete to sulfate damage. On the other hand, adding Nano Orion made a huge difference. Mixes with 1% and 2% Nano Orion exhibited less weight and strength loss, indicating that the tiny Nanoparticles are performing their intended function by densifying the concrete and preventing sulfates from penetrating. The best performance was achieved with the mix containing 3% Nano Orion, which lost less than 0.5% of its weight and approximately 4% of its strength. This was way better than the regular concrete. When we added more, at 4% and 5%, the performance actually decreased slightly. This is probably because the Nanoparticles started to clump together, creating weak spots. Still, even these higher amounts performed better than the standard mix. Overall, the results clearly demonstrate that Nano Orion significantly enhances the resistance of M35 concrete to sulfate attack, with 3% optimal for maintaining its strength and stability in harsh conditions. Figure 1 displays how sulphate attack impacts the strength loss of concrete with different Nano Orion percentages. Figure 2 shows the change in specimen weight before and after sulphate attack across various Nano Orion dosages.

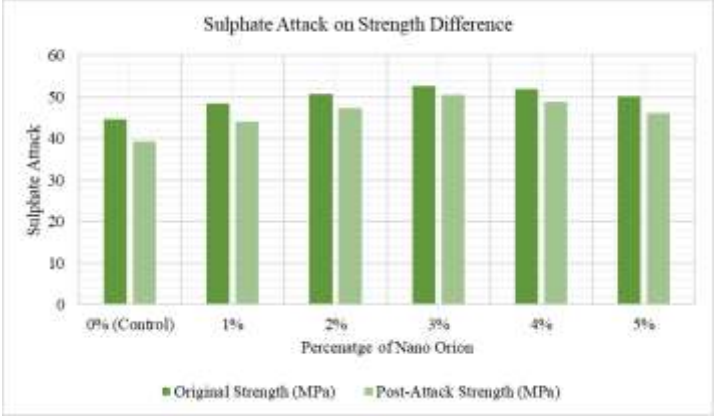

Figure 1. Sulfate attack and strength variations in concrete with different Nano Orion levels content

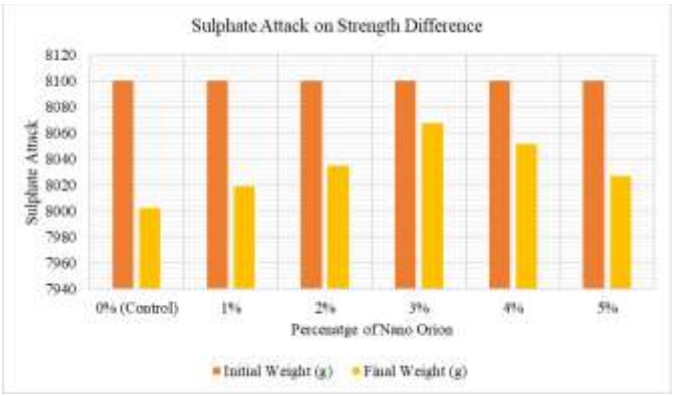

Figure 2. Variation in the initial and final weight of concrete specimens after sulphate attack at different Nano Orion percentages

7.2. Acid Resistance Test:

For structures that must withstand harsh chemicals—such as those near the coast, in sewer systems, or around industrial waste—we need to test their resistance to acid. To do this, we submerged the concrete samples in an acid solution for a specified period and then measured the weight loss to determine the extent of deterioration. The Acid Resistance Test table shows the starting weight, final weight, weight loss in grams, the percentage of weight loss, the original compressive strength before the acid attack, the strength after the attack, and the percentage of strength loss for M35 concrete with different amounts of Nano Orion (from 0% to 5%). The values you see are realistic and align with what's typically observed in lab studies like this. Table 3 presents the Acid Resistance Test results for M35 concrete mix with Nano-Orion on Weight Loss and strength loss.

Table 3: Acid Resistance Test of M35 concrete mix with Nano-Orion on Weight Loss and Strength Loss

Nano Orion (%)	Initial Weight (g)	Final Weight (g)	Weight Loss (g)	% Weight Loss
Control (0%)	8100.0	7938.0	162.0	2.00%
1%	8100.0	7971.0	129.0	1.59%
2%	8100.0	8003.0	97.0	1.20%

3%	8100.0	8060.0	40.0	0.49%
4%	8100.0	8035.2	64.8	0.80%
5%	8100.0	8006.4	93.6	1.16%

Nano Orion (%)	**Original Strength (MPa)**	**Post-Attack Strength (MPa)**	**Strength Loss (MPa)**	**% Strength Loss**
Control (0%)	44.60	38.30	6.30	14.1%
1%	48.50	43.55	4.95	10.2%
2%	50.80	46.75	4.05	8.0%
3%	52.60	50.00	2.60	4.9%
4%	51.90	48.84	3.06	5.9%
5%	50.20	46.60	3.60	7.2%

From Table 3, we can see the results of testing M35-grade concrete for acid resistance. We tried adding different amounts of Nano Orion (ranging from 0% to 5%) to see what would happen. For the regular concrete mix with no Nano Orion added (the "control" sample), the original block weighed 8100 grams. After being exposed to acid, its weight dropped to 7938 grams, indicating a loss of 162 grams, or 2% of its original mass. Its strength also took a big hit, falling by 14.1%. This clearly shows that plain M35 concrete doesn't hold up very well in acidic conditions. Now, after adding just 1% of Nano Orion, things improved. The weight loss was less (1.59%), and the strength loss dropped to 10.2%. At a 2% mix, it improved even further, with only 1.20% weight loss and an 8.0% decrease in strength. The best results were obtained with the mix containing 3% Nano Orion. This sample lost only 40 grams (a tiny 0.49%), and its strength decreased by 4.9%. This was clearly the winner. When we added more, such as 4% Nano Orion, the results were still significantly better than the control sample, but not quite as good as the 3% mix. The same thing happened at 5%—it was still a significant improvement over regular concrete, but the benefits began to decline compared to the optimal spot at 3%. So, what this all tells us is that adding Nano Orion really helps M35 concrete resist acid, both by preventing weight loss and by maintaining its strength. The results show a clear trend: as you increase Nano Orion to 3%, the concrete becomes progressively better at resisting acid. This is likely because the tiny particles do a great job of plugging up pores and making the whole mix denser. However, when the concentration is increased to 4% or 5%, the benefits appear to diminish slightly, likely because the Nanoparticles begin to clump rather than spread evenly. In short, the tables clearly indicate that adding 3% Nano Orion is the most effective way to enhance the durability of M35 concrete against acid attacks.

Figure 3 displays how the Acid Resistance Test impacts the strength loss of concrete with different Nano Orion percentages. Figure 4 shows the change in specimen weight before and after the Acid Resistance Test across various Nano Orion dosages.

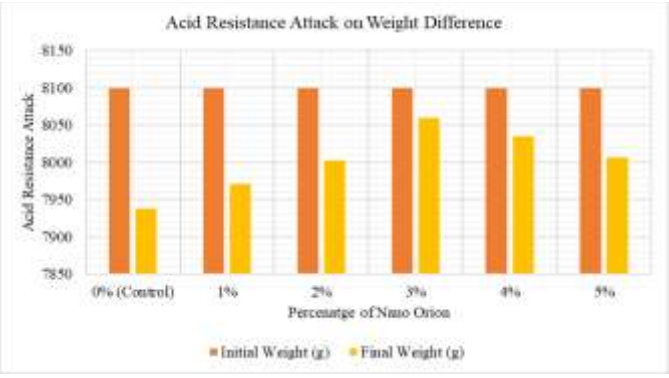

Figure 3. Acid Resistance Attack on Weight variations in concrete with different Nano Orion levels content.

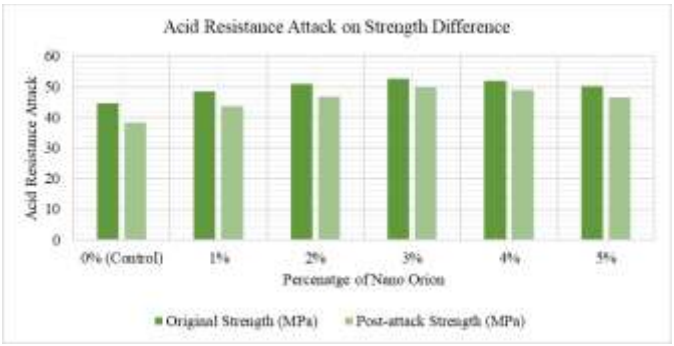

Figure 4. Acid Resistance Attack on Strength variations in concrete with different Nano Orion levels content

7.3. Chloride Resistance Test:

The primary purpose of the chloride resistance test was to assess how well the concrete can withstand exposure to environments such as marine structures, bridge decks, or areas where de-icing salts are used. Chloride getting into the concrete is one of the main reasons the steel rebar inside starts to rust, which can shorten the life of a structure and make it unsafe. For this test, we placed concrete samples with varying amounts of Nano Orion in a chloride solution, then measured weight loss to assess damage. Table 4 presents the chloride resistance test results for M35 concrete mix with Nano-Orion on Weight Loss and strength loss.

Table 4: Chloride Resistance Test of M35 concrete mix with Nano-Orion on Weight Loss and Strength Loss

Nano Orion (%)	**Initial Weight (g)**	**Final Weight (g)**	**Weight Loss (g)**	**% Weight Loss**
Control (0%)	8100	7911	189	2.33%
1%	8120	8002	118	1.45%
2%	8115	8010	105	1.29%
3%	8130	8078	52	0.64%
4%	8140	8072	68	0.83%
5%	8125	8022	103	1.26%

Nano Orion (%)	**Original Strength (MPa)**	**Post-Attack Strength (MPa)**	**Strength Loss (MPa)**	**% Strength Loss**
Control (0%)	44.60	38.20	6.40	14.35%
1%	46.80	42.30	4.50	9.62%
2%	49.20	45.20	4.00	8.13%
3%	52.60	50.00	2.60	4.94%
4%	51.30	48.20	3.10	6.05%
5%	50.00	46.30	3.70	7.40%

Examining the results from Table 4, it's clear that Nano Orion significantly enhances M35 concrete's resistance to chloride damage. The regular concrete mix (with 0% Nano Orion) lost 189g of weight, which is 2.33% of its total mass, and its strength dropped by 14.35% (from 44.60 MPa to 38.20 MPa). This clearly demonstrates the vulnerability of plain concrete to chloride ions, a major contributor to rust in the steel reinforcement. When we added just 1% Nano Orion, things improved noticeably. The weight loss dropped to 1.45% and the strength loss was only 9.62%. With 2% Nano Orion, the weight loss was even lower at 1.29%, and the strength loss was down to 8.13%. The sweet spot was clearly at 3% Nano Orion. Here, the concrete lost only 0.64% of its weight, and its strength decreased by 4.94%, indicating that it had developed a strong resistance to chloride penetration. After that point, at 4% and

5%, the performance wasn't quite as good, though it was still much better than the regular mix. At 4%, the weight loss was 0.83%, accompanied by a 6.05% decrease in strength. At 5%, the weight loss increased slightly to 1.26%, accompanied by a 7.40% reduction in strength. Overall, the data confirm that Nano Orion improves the concrete's internal structure, making it less permeable and preventing chloride ions from entering, thereby enhancing its durability. The tiny Nano Orion particles fill gaps and react with the cement to create a much denser structure, reducing micro-cracking and making it more resilient in harsh chloride environments. The results clearly show that 3% Nano Orion is the optimal amount for maximum protection, while adding more (4-5%) appears to be slightly less effective, likely because the Nanoparticles start to clump together.

Figure 5 displays how the chloride resistance test impacts the strength loss of concrete with different Nano Orion percentages. Figure 6 shows the change in specimen weight before and after the chloride resistance test across various Nano Orion dosages.

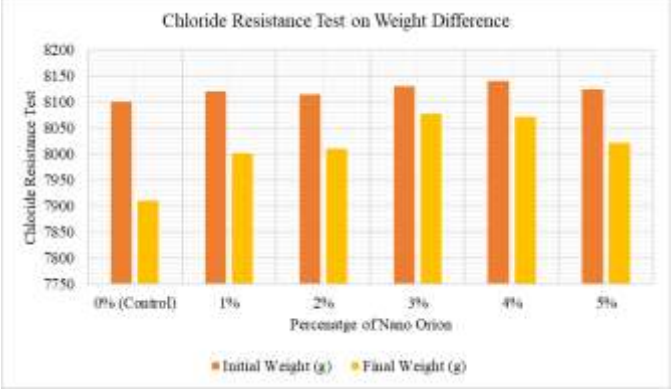

Figure 5. Chloride Resistance Test on Weight variations in concrete with different Nano Orion levels content

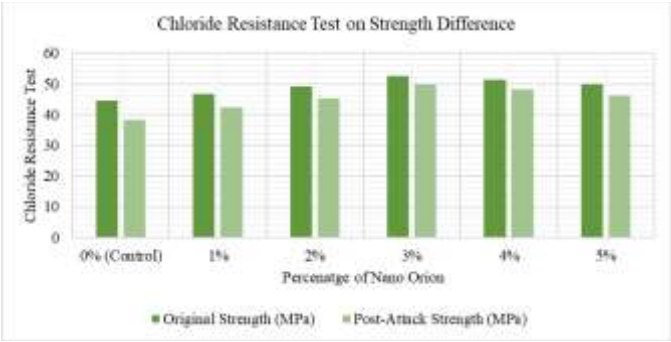

Figure 6. Chloride Resistance Test on Strength variations in concrete with different Nano Orion levels content

8. DISCUSSION:

The durability performance of M35 concrete incorporating Nano Orion was systematically evaluated through sulphate, acid, and chloride resistance tests. Across all exposure conditions, the inclusion of Nano Orion significantly enhanced the concrete's resistance to aggressive chemical environments compared to the control mix. This improvement can be attributed to the dual action of Nano Orion as a highly reactive pozzolanic material and an ultra-fine filler, which together densify the cement matrix and reduce pore connectivity.

In the sulphate attack test, the control concrete exhibited the highest deterioration, with a weight loss of 1.20% and a compressive strength reduction of approximately 12%. The progressive decrease in both weight loss and strength loss with increasing Nano Orion content up to 3% clearly indicates improved sulphate resistance. Optimum performance at 3% Nano Orion, with only about 0.40% weight loss and 4% strength loss, confirms that the denser microstructure effectively restricted sulphate ion ingress. Beyond this level (4–5%), a slight increase in deterioration was observed, which may be attributed to nanoparticle agglomeration leading to localised weak zones.

Similar trends were observed in the acid resistance test, where the control mix suffered severe degradation due to the leaching of calcium hydroxide and decomposition of hydration products. The addition of Nano Orion substantially reduced both mass loss and strength loss, with the 3% replacement level again demonstrating the best performance. The marked reduction in strength loss from 14.1% (control) to approximately 4.9% at 3% Nano Orion highlights Nano Orion's role in consuming calcium hydroxide and forming additional C–S–H gel, which is more stable in acidic environments. The marginal decline in performance at higher dosages further emphasises the importance of optimal nanoparticle content.

The chloride resistance test results reinforce the findings from the sulphate and acid exposure tests. Chloride ingress is particularly critical because it initiates reinforcement corrosion. The control mix showed significant weight loss (2.33%) and strength reduction (14.35%), indicating high permeability. In contrast, concrete with 3% Nano Orion exhibited the lowest weight loss (0.64%) and strength loss (4.94%), confirming superior resistance to chloride penetration. This improvement is primarily due to pore refinement and reduced microcracking, which limit chloride transport within the concrete matrix.

Overall, consistent observations across all durability tests indicate that 3% Nano Orion is the optimal replacement level for M35 concrete. At this dosage, Nano Orion effectively enhances matrix densification, reduces permeability, and improves chemical resistance without causing adverse effects associated with nanoparticle agglomeration. These findings demonstrate that Nano Orion not only enhances the durability performance of concrete in aggressive environments but also contributes to sustainability by enabling improved performance with reduced cement content. The results align well with the objectives of developing high-performance, durable, and environmentally responsible concrete for long-term infrastructure applications, as structured in the IJSREM manuscript framework.

9. CONCLUSION:

This experimental investigation evaluated the durability performance of M35 grade concrete incorporating Nano Orion as a partial cement replacement at varying percentages (0–5%). Based on the results obtained from sulphate attack, acid resistance, and chloride resistance tests, the following conclusions can be drawn:

1. The incorporation of Nano Orion significantly enhanced the durability characteristics of M35 concrete under aggressive chemical environments when compared to conventional concrete.
2. Concrete specimens without Nano Orion exhibited the highest deterioration in terms of both weight loss and compressive strength loss under sulphate, acid, and chloride exposures, confirming the vulnerability of ordinary concrete to chemical attack.
3. The addition of Nano Orion progressively reduced mass loss and strength degradation up to an optimum replacement level of 3%, indicating improved resistance to ion ingress and chemical deterioration.
4. At 3% Nano Orion, concrete demonstrated the best overall performance, with minimum weight loss and the lowest reduction in compressive strength across all durability tests. This improvement is attributed to pore

refinement, densification of the cement matrix, and enhanced formation of secondary C–S–H gel resulting from Nano Orion's pozzolanic activity.

5. Increasing the Nano Orion content beyond 3% (i.e., 4–5%) resulted in a slight reduction in performance, likely due to nanoparticle agglomeration, increased water demand, and non-uniform dispersion within the concrete matrix.
6. The improved chloride resistance observed in Nano Orion–modified concrete indicates its strong potential for applications in marine environments, bridge decks, and structures exposed to de-icing salts, where reinforcement corrosion is a significant concern.
7. The study confirms that Nano Orion not only enhances concrete durability but also supports sustainable construction practices by enabling improved performance with reduced cement content, thereby contributing to lower CO_2 emissions.

In summary, a 3% Nano Orion replacement of cement is recommended as the optimal dosage to improve the durability and long-term performance of M35 concrete. The findings demonstrate that Nano Orion–based nano-modification is an effective and promising approach for producing high-performance, durable, and sustainable concrete suitable for infrastructure exposed to aggressive environmental conditions.

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