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Analyzing Colour Stability as a Measure of Chemical Induced Deterioration in High Strength Concrete

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ABSTRACT: This study explores how image-based analysis can be related to Changes in the color profiles of deteriorated M50 grade High Strength Concrete (HSC) in relation to variations in residual strength and durability.The concrete cubes are submerged at intervals of 7, 14, 28, and 56 days in 5% solutions of sodium chloride (NaCl), hydrochloric acid (HCL), sulfuric acid (H_2SO_4), and acetic acid (CH_3COOH). The surface deterioration was captured through image-based analysis by using the CIE-XYZ colour space, with a focus on chromaticity diagrams. The investigation addresses how different chemicals and immersions times affect colour profiles, taking into account factors such as reagent absorption, necessary concentrations for chemical reactions, and the rates of these reactions. This approach provides a detailed, objective method for detecting damage and understanding the impact of deterioration on the strength and durability of M50 grade concrete.

KEYWORDS: Chromaticity, CIE-XYZ colour space, Image-Based analysis, chemical exposures.

I. INTRODUCTION

Concrete is a vital material in construction, known for its durability and adaptability. Among its various types, High Strength Concrete (HSC), especially the M50 grade, is high valued for challenging applications like bridges, skyscrapers, and roadways due its superior strength and long-lasting nature. Despite its robustness, HSC can still suffer from deteriorate when unveil to harsh environmental conditions and strong chemicals, which can gradually affect its performance and structural integrity.

Grasping how chemical exposure affects High Strength Concrete (HSC) is crucial for predicting its long-term durability and maintaining structural safety. This study seeks to fill this gap by using image-based analysis to track how different chemicals impact M50 grade concrete. We examine how alterations in the color profiles of degraded concrete correspond to changes in its remaining strength and overall durability.

Chromaticity, the method of examining colour within a standardized colour framework, is essential to this study.
To explore this, concrete cubes were immersed in 5% solutions of sodium chloride (NaCl), hydrochloric acid (HCl), sulfuric acid (H_2SO_4), and acetic acid (CH_3COOH). These cubes were exposed to the solutions for different time periods at 7, 14, 28, and 56 days to observe how chemical exposure impacts the concrete over time. The deterioration was meticulously recorded using image J software in advanced imaging techniques, with a focus on analyzing changes in colour profiles through CIE-XYZ colour space and chromaticity diagrams, how various chemical environments and immersion periods affect the colour changes in concrete. We examine crucial factors such as how quickly the concrete absorbs reagents, the concentrations need to start chemical reactions, and the dynamics of these reactions. By analyzing colour changes through chromaticity, we not only improve our ability to detect deterioration but also gain a better understanding of how chemical exposures affect the strength and durability of M50 grade concrete.

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II. LITERATURE REVIEW

Anish Banerjee et al.[1] their research show that effectiveness of colourimetric methods and image-based analysis for assessing concrete deterioration, Using CIE-XYZ colour space and chromaticity diagrams allows precise measurement of colour changes due to chemical exposure, revealing how these changes relate to concrete's strength and durability. Different chemicals cause unique colour shifts, enhancing the accuracy of damage evaluations. V guru prathap reddy et al.[2] the study highlights how 30 MPa concrete deteriorates when exposed to 5% solutions of hydrochloric acid (HCl), sulfuric acid (H_2SO_4), sodium chloride (NaCl), and magnesium sulfate ($MgSO_4$) over periods of 3, 7, 14, and 28 days, Using the CIE-LAB colour space, the research shows significant colour changes for HCl and H_2SO_4, indicating more severe damage compared to NaCl and $MgSO_4$. Didem Eren Sarıcı et al.[3] This study examines the impact of thermal degradation on marble surfaces, emphasizing changes in gloss and colour parameters. Utilizing CIE-XYZ colour space for image-based analysis, the results indicate significant alterations in chromaticity due to chemical exposures and temperature-induced deterioration, providing critical insights into the material's vulnerability under extreme conditions. S Karaman et al.[4]This research utilized Image-Based analysis to examine the colour changes in concrete surfaces subjected to various chemical exposures. The study found a strong relationship between the intensity of colour alteration and the level of chemical damage. By applying the CIE-XYZ colour space for chromaticity evaluation, significant shifts in the colour properties of concrete in aggressive environments were observed, demonstrating the method's effectiveness in detecting surface degradation. These findings suggest that colourimetric analysis could serve as a valuable non-destructive approach for assessing concrete quality under challenging chemical conditions. V guru prathap reddy et al.[5] his study uses digital image analysis to assess concrete deterioration from chemical exposure. M30 grade concrete cubes were exposed to 5% solutions of hydrochloric acid (HCl), sulfuric acid (H2SO4), sodium chloride (NaCl), and magnesium sulfate (MgSO4) for up to 28 days. Grayscale intensity from images effectively predicted changes in concrete mass and strength, with HCl and MgSO4 showing the most significant effects. HCl led to notable strength loss and surface cracking, while MgSO4 caused relatively less damage. The analysis demonstrated strong correlations between grayscale intensity and compressive strength, especially for HCl and MgSO4. M K Gokay et al.[6] This research explores the impact of chemical exposure on the colour properties of concrete, employing Image-Based analysis within the CIE-XYZ colour space. The results demonstrate that chemical exposure leads to significant changes in the chromaticity of concrete surfaces. These changes can be effectively quantified, offering a non-destructive approach to evaluate concrete durability under different environmental conditions. The study underscores the utility of CIE-XYZ colour space measurements in assessing the effects of chemical exposure on concrete. E Annerel et al.

III. MATERIALS

In this study, high-strength concrete (HSC) with a target compressive strength of 50 MPa was utilized. The mix design included materials such as fine aggregate, coarse aggregate, water, and cement, all selected and proportioned according to Indian standard codes IS 10262–2019 and IS 456-2000. Concrete cubes with dimensions of 150 × 150 × 150 mm were cast and subjected to testing as per the procedures outlined in Indian standard IS:516-2018 (BIS, 2018), as summarized in Table 1.

Table-1 Mix Proportions obtained as per IS 10262–2019

S.NO	MATERIALS	DENSITY (Kg/m^3)
1	Cement	435
2	Water	148
3	Water cement ratio	0.34
4	Fine aggregate	720
5	Coarse aggregate-20mm	717
6	Coarse aggregate-10mm	478
7	Super plasticizer	4.35

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3.1. Cement

The cement utilized in this study was ordinary Portland cement (OPC) of 53 grade, produced by JSW, in compliance with the IS 12269:2013 standard. It has a specific gravity of 3.15.

3.2. Fine aggregate

For this study, locally sourced river sand was selected as the fine aggregate. The sand passed through a 4.75mm IS sieve, adhered to the grading zone-II requirements specified in IS:383-2016, and had a specific gravity of 2.65.

3.3. Coarse aggregate

In this study, the coarse aggregate mix was composed of 60% 20mm-sized aggregate and 40% 10mm-sized aggregate, chosen to optimize the balance between strength, durability, and workability in the concrete mixture. The materials adhered to the relevant standards and had a specific gravity of 2.70, meeting the requirements specified in IS:383-2016.

3.4. Super plasticizer

The Fosroc Conplast SP-600, a high-range water-reducing admixture was used in this study, with a specific gravity of 1.22, was incorporated into the concrete mix to enhance workability and reduce water content. This admixture complies with ASTM C494 (2015) standards and is suitable for improving concrete strength and durability.

3.5. Water

The water used for the concrete mix conformed to the quality standards specified in IS 10500:2012, ensuring it was free from harmful impurities that could affect the concrete's strength and durability. This standard was referenced to maintain the integrity and performance of the concrete.

3.6. CH_3COOH (Acetic acid)

In this study analytical grade acetic acid (CH_3COOH) with a purity of 99.8% was used, to evaluate its influence on the concrete surface and its mechanical strength over time. This high-purity acid, obtained from Molychem, was chosen for its strong acidic properties, making it a suitable candidate for studying its impact on the curing process of concrete. The acetic acid used complies with IS 265:1993, the Indian Standard for acetic acid.

3.7. NaCl (Sodium chloride)

In this study Sodium Chloride LR (NaCl) with a purity of 99%, provided by Molychem was used. This high-purity reagent, adhering to Indian Standard IS 797:1982, is essential for various chemical analyses and is frequently employed in experiments requiring a reliable source of sodium chloride. Commonly referred to as salt, it was used to assess the effects of saline conditions on concrete deterioration.

3.8. HCL (Hydrochloric acid)

In this study, Hydrochloric Acid (HCl) with a concentration of 35-37%, obtained from Molychemwas used, conforming to Indian Standard IS 265. This strong acid, critical for various chemical evaluations, was used to investigate its impact on both the surface and overall durability of the concrete.

3.9. H_2SO_4 (Sulfuric acid)

In this investigation, 98% pure sulfuric acid (H_2SO_4) provided by Emparta, as per IS 266:1993, was used to assess the impact of sulfate exposure on concrete, specifically focusing on changes in colour and strength. Concrete's durability and structural integrity were evaluated by monitoring these alterations in response to the acid's corrosive effects.

IV. METHODOLOGY

To evaluate the effects of specific chemical agents on concrete, fifty-four cubic specimens with 150 mm sides were cast. These specimens were subjected to four exposure durations (7, 14, 28, and 56 days) in solutions containing 5% concentrations of acetic acid, sodium chloride, hydrochloric acid, and sulfuric acid to evaluate their strength and durability characteristics.

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4.1. Compressive strength

After 28-day standard curing, samples are evaluated for compressive strength to determine a reference value for further analysis as shown in Figure-1. Then, the compressive strength of the samples exposed to different reagent solutions was measured using constant loading speed, according to the methods specified in the Indian Standard IS: 516-2018 (BIS, 2018).

Figure-1: **Compression testing**

4.2. Image Acquisition and Preprocessing

Images of samples were taken in both their original and reagent-exposed conditions using standard RGB cameras. The undamaged control cubes served as the baseline reference, with medium-indoor lighting consistently applied. All six faces of each sample were photographed, including control cubes and those immersed in reagents for 7, 14, 28 and 56 days. A Lux-meter was used for reference and light intensity to ensure consistent lighting conditions, crucial for accurate and uniform image analysis.

4.3. Evaluation of Surface Deterioration with ImageJ

The open-source Java-based software ImageJ was used to calibrate and analyze the images. This software enabled the assessment of colour profiles for samples exposed to various reagents such as acetic acid (CH_3COOH), sodium chloride (NaCl), hydrochloric acid (HCl), and sulfuric acid (H2SO4), over periods of 7, 14, 28, and 56 days. 3-D surface plots were generated to visualize the deterioration across all six faces of each sample.

4.4. Chromaticity Evalution

Different color models can demonstrate how the color profiles of samples change when exposed to various reagents over 7, 14, 28, and 56 days. The RGB color model,which functions in a three-dimensional (3D) space with intensity values for red, green, and blue ranging from 0 (black) to 255 (white), is commonly used to analyze colour alterations on deteriorated surfaces. However, RGB histograms may exhibit negative values when plotted in a two-dimensional (2D) format because of the model's three-dimensional nature. Moreover, since RGB is device-dependent, color information can differ across various displays, making it less dependable for consistent comparisons.This approach was applied to samples treated with acetic acid (CH3COOH), sodium chloride (NaCl), hydrochloric acid (HCl), and sulfuric acid (H2SO4).

V. RESULTS AND DISCUSSION

5.1. Compression test

The Table-2 presents data on the compressive strength of concrete samples subjected to different acids over a 56-day period, all starting from an initial strength of 58.02 N/mm^2. It shows that exposure to HCl led to a 23.5% reduction in compressive strength, bringing it down to 44.37 N/mm^2. In contrast, the NaCl-treated samples exhibited a smaller decline of 7.5%, with strength decreasing to 53.64 N/mm^2. Similarly, exposure to CH_3COOH resulted in an 8.2% reduction, reducing the strength to 53.27 N/mm^2. The most significant deterioration occurred in the samples immersed in H_2SO_4, which saw a 28.0% drop in compressive strength, falling to 41.77 N/mm^2. These findings highlight the differential impact of various acids on concrete durability, with sulfuric acid causing the most severe degradation.

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TABLE-2 COMPRESSIVE STRENGTH BEFORE AND AFTER IMMERSION IN ACID

S.NO	NAME OF ACID	COMPRESSION STRENGTH BEFORE IMMERSION IN ACID (N/mm2)	COMPRESSION STRENGTH AFTER IMMERSION ACID (N/mm2)			
		28-DAYS	7 -DAYS	14-DAYS	28-DAYS	56-DAYS
1	HCL	58.02	56.33	52.26	49.15	44.37
2	NACL	58.02	57.72	56.34	54.93	53.64
3	CH_3COOH	58.02	57.72	55.37	53.55	53.27
4	H_2SO_4	58.02	56.79	53.53	46.38	41.77

5.2. Visual analysis of HSC samples exposed to Reagents

Images of concrete cubes, including control samples and those subjected to different reagents, were captured under consistent lighting conditions, as confirmed by a Lux-meter. The analysis revealed that control samples retained their original appearance, while cubes exposed to reagents showed notable changes in colour and surface texture. These changes became more evident with longer exposure times, especially after 56 days, indicating significant surface degradation.

Figure 2: Control sample before immersion in chemicals.

Figure 3: Hydrochloric acid immersion at 5% concentration after (a) 7 days, (b) 14 days, (c) 28 days, and (d) 56 days.

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(a) 7-days (b) 14-days

(c) 28-days (d) 56-days

Figure 4: Sodium chloride immersion at 5% concentration after (a) 7 days, (b) 14 days, (c) 28 days, and (d) 56 days.

(a) 7-days (b) 14-days

(c) 28-days (d) 56-days

Figure 5: Acetic acid immersion at 5% concentration after (a) 7 days, (b) 14 days, (c) 28 days, and (d) 56 days.

(a) 7-days (b) 14-days

(c) 28-days (d) 56-days

Figure 6: Sodium sulfate immersion at 5% concentration after (a) 7 days, (b) 14 days, (c) 28 days, and (d) 56 days.

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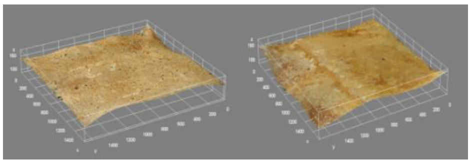
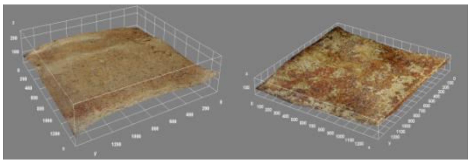
The uniform lighting ensured accurate and reliable image analysis. The observed visual changes in the reagent-exposed samples confirm that reagent exposure impacts the concrete's surface properties. The increasing colour and texture changes with longer exposure indicate measurable degradation. This demonstrates the utility of image analysis in evaluating concrete quality and monitoring material changes over time.

5.3. Colour Profile Analysis and Degradation Assessment Using Image J

To analyze the calibrated images, we used Image J, an open-source software based on Java. This tool is well-regarded in medical imaging for tasks like 3D live-cell imaging and radio logistical analysis, and it's also useful in civil engineering for examining digital images. Image J helps us visualize the deterioration of concrete samples over different periods 7, 14, 28 and 56 days-by analyzing the calibrated images and generating detailed 3D surface maps. The study focused on M50 grade High-Strength Concrete (HSC) samples, analyzing all six faces of each cube. Figures 7 through 10 illustrate the most severely deteriorated faces of these HSC M50 cubes following exposure to different chemicals over various durations.

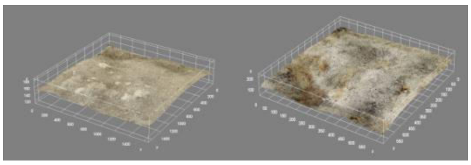


(a) 7-days (b) 14-days

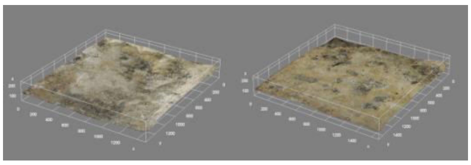


(c) 28-days (d) 56-days

Figure 7: 3D surface plots of surface deterioration due to hydrochloric acid (HCl) immersion at a 5% concentration after (a) 7 days, (b) 14 days, (c) 28 days, and (d) 56 days.



(a) 7-days (b) 14-days



(c) 28-days (d) 56-days

Figure 8: 3D surface plots of surface deterioration due to sodium chloride (NaCl) immersion at a 5% concentration after (a) 7 days, (b) 14 days, (c) 28 days, and (d) 56 days.

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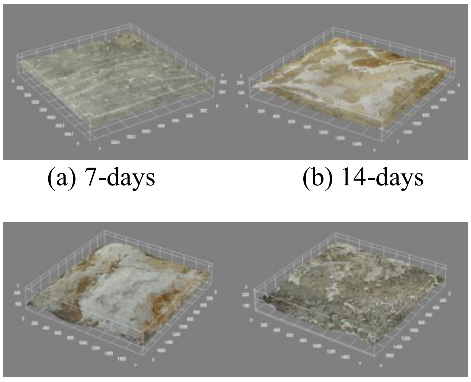
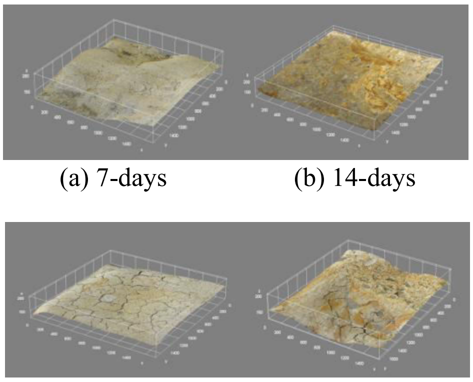


(a) 7-days (b) 14-days

(c) 28-days (d) 56-days

Figure 9: 3D surface plots of surface deterioration due to acetic acid (CH_3COOH) immersion at a 5% concentration after (a) 7 days, (b) 14 days, (c) 28 days, and (d) 56 days.



(a) 7-days (b) 14-days

(c) 28-days (d) 56-days

Figure 10: 3D surface plots of surface deterioration due to sulfuric acid (H_2SO_4) immersion at a 5% concentration after (a) 7 days, (b) 14 days, (c) 28 days, and (d) 56 days.

Figure 7 illustrates the effects of hydrochloric acid (HCl), with the calibrated surface plots indicating a notable shift toward red. Initial discoloration occurred with exposure to sodium chloride (NaCl) and acetic acid (CH_3COOH), which was later followed by the appearance of white patches, as depicted in Figures 8 and 9. However, the changes in colour for these exposures were less dramatic compared to the more pronounced shifts observed with hydrochloric and sulfuric acids. In Figure 10, sulfuric acid (H_2SO_4) exposure is shown to cause deterioration through the formation of ettringite, resulting in a noticeable shift to a white colour in the images.

5.4. Analysis of chromaticity

To accurately quantify visual colour changes, we first analyze the RGB values of pixels showing severe deterioration. These values are then converted into CIE-XYZ coordinates using polynomial transformation equations.In the CIE-XYZ color space, the Z component influences only the brightness, enabling color information to be represented on the XY plane with Z set to 0 (see Figure 6). This approach ensures that variations in light intensity affect only the plane level, not the color data itself. Plotting the x and y coordinates from the CIE-XYZ values on a 2D graph provides an accurate numerical representation of the color information.that changes in light intensity only affect the plane level, not the colour data itself. This approach provides a detailed and standardized depiction of colour changes, enabling accurate assessment of the concrete's deterioration.

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The process for creating a chromaticity diagram involves the following steps:

(a) Begin by extracting RGB color data from the calibrated image of the degraded concrete surface is obtained by averaging the RGB values of selected pixels that most accurately reflect the overall color profile of the image.

(b) Convert the RGB values to the XYZ colour space using polynomial transformations.

$$X=0.41245\times R+0.35758\times G+0.18042\times B$$
$$Y=0.21267\times R+0.71516\times G+0.07217\times B$$
$$Z=0.01933\times R+0.11919\times G +0.95023\times B$$

where R, G, and B represent the color coordinates within the RGB color space.

(c) To remove the influence of light intensity, the RGB values are normalized and mapped onto the X-Y plane (with Z=0). The x and y coordinates are then determined using the following approach:

$$x = \frac{x}{x+y+z}$$
$$y = \frac{y}{x+y+z}$$

The aim was to select pixels that most precisely capture the color variations on the degraded concrete surface. We explored various methods for selecting regions of interest, including rectangular and random pixel-based approaches (see Figure 11). For our study, we chose rectangular and polygonal regions that covered a significant number of pixels. By converting the most frequent RGB values, or mode values, from these areas' colour histograms into CIE - XYZ values, we effectively captured the primary colour characteristics of these regions.

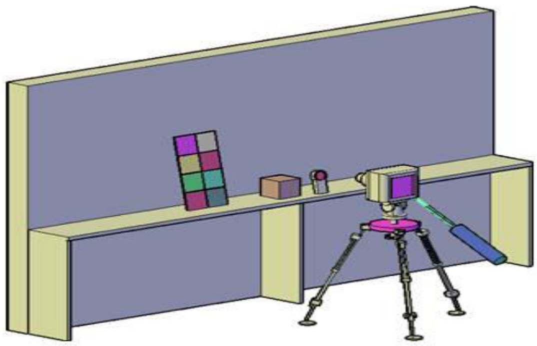

Figure 11 : Experimental set up for image capturing.

In contrast, random pixel selection yielded less reliable mode values due to the smaller number of pixels. Thus, we used the average RGB values from these randomly selected pixels for analysis. The differences between the mode values from the rectangular and polygonal methods and the mean values from the random pixel method were minimal, ensuring reliable colour information across the analyzed images. To further validate our results, we also analyzed two or three additional, less deteriorated faces of each cube. Following the selection of pixels from calibrated images.

The Chromaticity Coordinates (x, y) for HCl immersion revealed a significant shift toward red, especially from the control sample to the 14-day immersion data, as shown in Figure 12. This observation aligns with visual assessments from 3D surface plots, which displayed a progression in red colouration over time. Additionally, a shift toward white was noted at the 28-day mark, indicating that the surface deterioration had progressed to the inner concrete layer.

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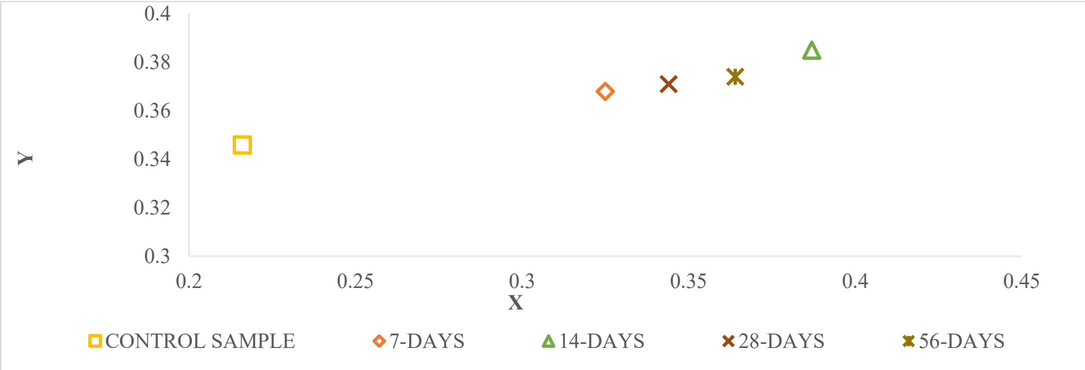

Figure 12. Evolution of Chromaticity Coordinates (x, y), illustrating the colour changes of the control sample and surfaces deteriorated by hydrochloric acid (HCl) immersion at a 5% concentration after (a) 3 days, (b) 7 days, (c) 14 days, and (d) 28 days.

The Figure 13 presents the relationship between Chromaticity Coordinates (x, y) for samples subjected to NaCl exposure over varying durations. The control sample exhibits the highest Y-value, indicating minimal impact from exposure. As the immersion period extends from 7 to 56 days, there is a noticeable shift in both X and Y values. The sample immersed for 7 days shows the lowest Y-value, while samples immersed for 14, 28, and 56 days display a gradual increase in Y-values. .

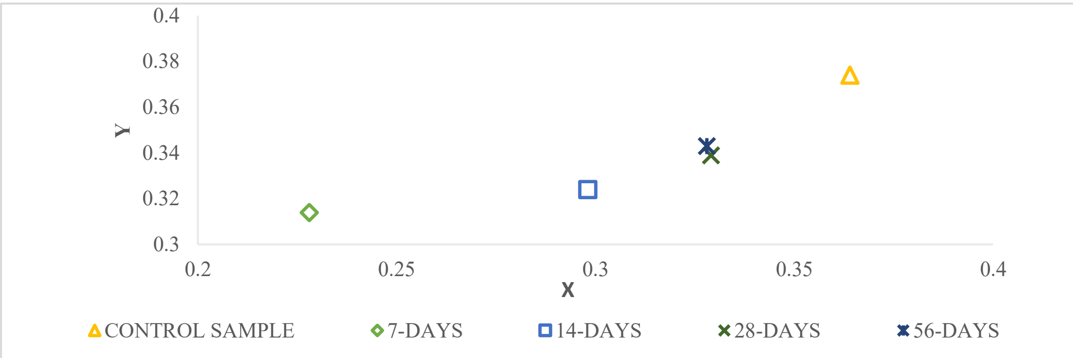

Figure 13. Evolution of Chromaticity Coordinates (x, y), illustrating the colour changes of the control sample and surfaces deteriorated by sodium chloride (NaCl) immersion at a 5% concentration after (a) 3 days, (b) 7 days, (c) 14 days, and (d) 28 days.

The Figure 14 illustrates the impact of CH_3COOH exposure on samples across different immersion periods. The control sample, which was not subjected to CH_3COOH, exhibits a higher Y-value than the samples immersed for 7, 14, 28, and 56 days. Notably, the 7-day immersion sample shows the lowest Y-value. As the exposure duration increases, there is a gradual rise in Y-values, with the 56-day immersion sample showing the highest value.

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Figure 14. Evolution of Chromaticity Coordinates (x, y), illustrating the colour changes of the control sample and surfaces deteriorated by acetic acid (CH_3COOH) immersion at a 5% concentration after (a) 3 days, (b) 7 days, (c) 14 days, and (d) 28 days.

The chromaticity coordinates (x, y) for H_2SO_4 samples exposed for different durations show a clear pattern of color changes. Initially, there is a slight shift from the control sample after 7 days of immersion. This is followed by a more significant movement toward higher x and y values at 14 days, reflecting a gradual increase in color saturation. This trend continues with further exposure, culminating in a marked shift towards the white region of the chromaticity diagram at 28 and 56 days was shown in Figure 15.

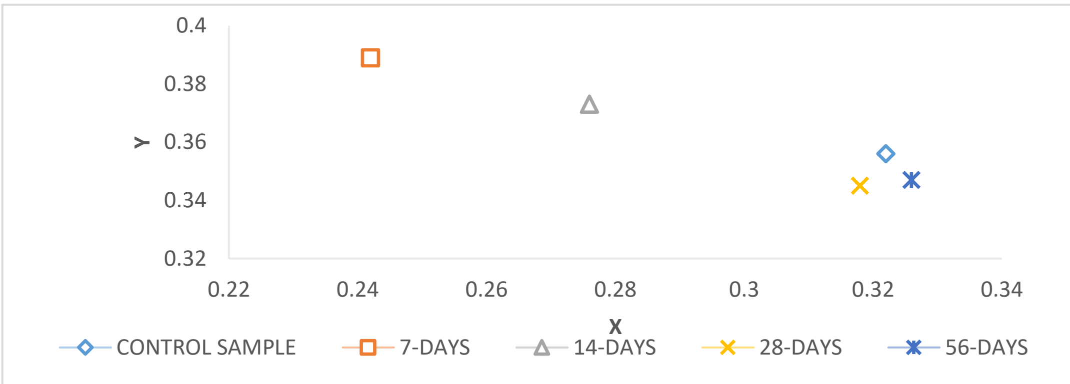

Figure 15. Evolution of Chromaticity Coordinates (x, y), illustrating the colour changes of the control sample and surfaces deteriorated by sulfuric acid (H_2SO_4) immersion at a 5% concentration after (a) 3 days, (b) 7 days, (c) 14 days, and (d) 28 days.

5.5 Relationship Between Chromaticity (x) and Compressive Strength

The Figure 16 shows that the relationship between chromaticity (x) and compressive strength was investigated through regression analysis, revealing a strong quadratic correlation with an R2R^2R2 value of 0.9907. The regression equation y=68735x2−64142x2+19396x−1831.7y = 68735x^2 - 64142x^2 + 19396x - 1831.7y=68735x2−64142x2+19396x−1831.7 demonstrates that compressive strength initially increases with higher chromaticity values, reaches a peak, and then begins to decline. This quadratic relationship suggests that chromaticity has a significant impact on compressive strength, indicating an optimal range for achieving maximum strength.

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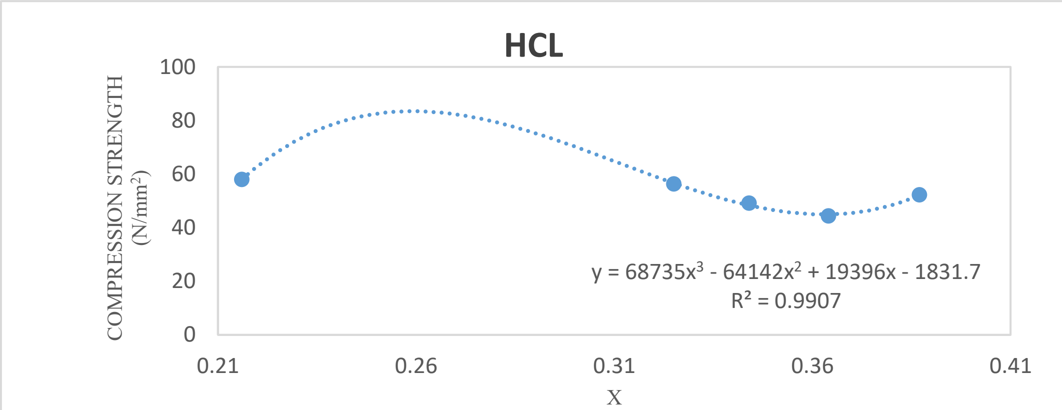

Figure 16: Correlation between compression strength and chromaticity (x) of Hcl

The Figure 17 shows a non-linear relationship between NaCl concentration and the measured property, with the polynomial fit given by y=−38197x2+31994x−8860.2x+867.7y = -38197x^2 + 31994x - 8860.2x + 867.7y=−38197x2+31994x−8860.2x+867.7 and a high R2R^2R2 value of 0.9046. The data indicates that the property increases with NaCl concentration up to about 0.24-0.25, after which it declines.This suggests an optimal NaCl concentration for enhancing the property, beyond which further increases may have diminishing or negative effects.

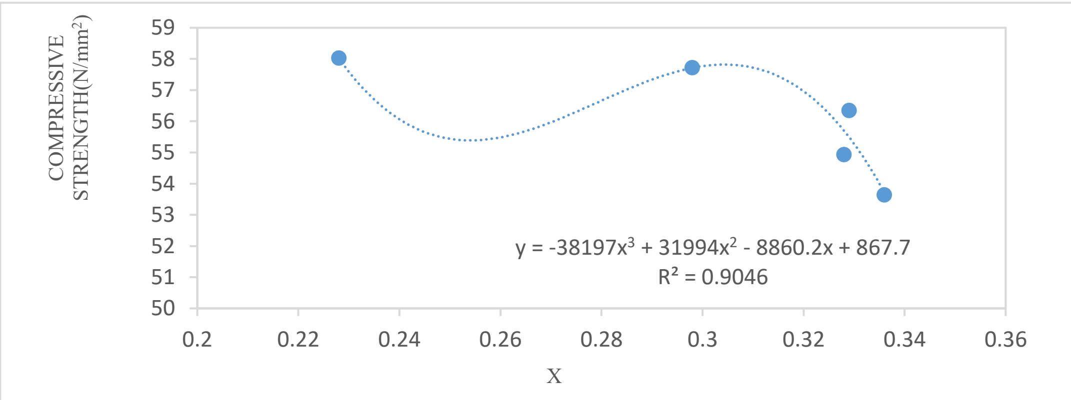

Figure 17: Correlation between compression strength and chromaticity (x) of NaCl

The Figure 18 representing the effect of acetic acid (CH_3COOH) concentration on the measured property shows a distinct non-linear pattern, best described by a second-degree polynomial equation y=3E+06x2−2E+06x2+721274x−69277, with an R^2 value of 0.998, indicating a highly accurate fit. The property increases sharply with concentration, peaking at around 0.26, followed by a notable decline as the concentration continues to rise. .

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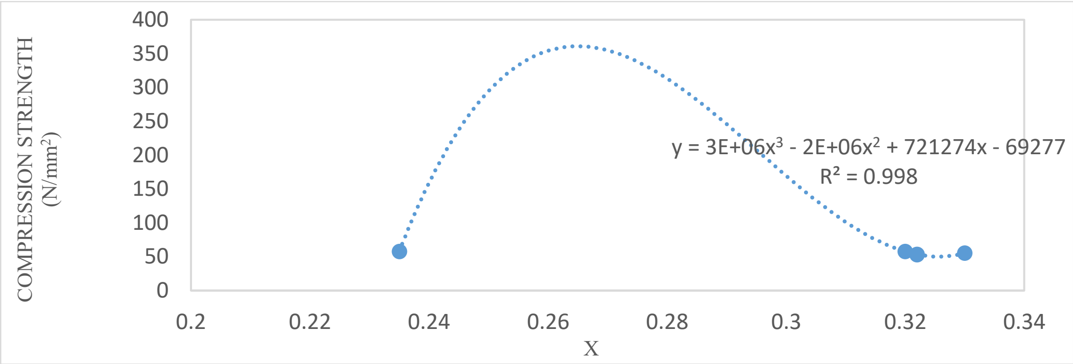

Figure 18: Correlation between compression strength and chromaticity (x) of CH_3COOH

The Figure 19 for sulfuric acid (H_2SO_4) concentration shows a downward trend in the measured property, which follows a polynomial relationship described by the equation y=−5382x2+2856.2x2−417.19x+67.897 with an R^2 value of 0.931, indicating a good fit. The property starts at a relatively high value but decreases steadily as the concentration of H_2SO_4 increases, suggesting that higher concentrations of sulfuric acid negatively impact the property being measured. This trend implies that as the concentration rises, the detrimental effects of sulfuric acid become more pronounced.

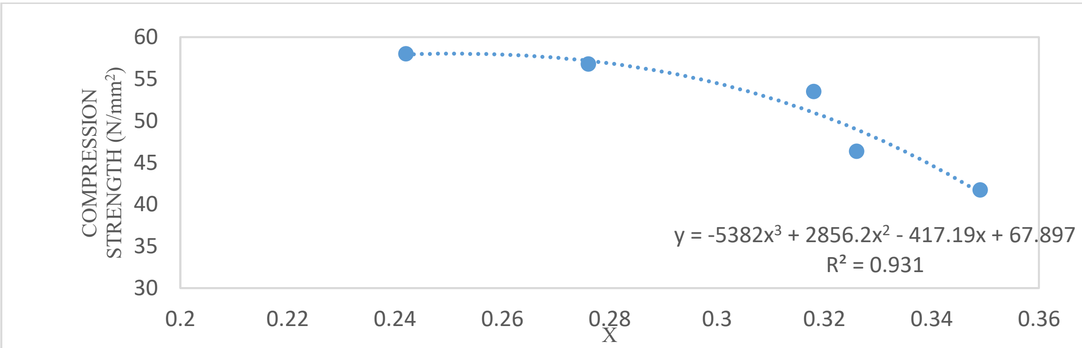

Figure 19: Correlation between compression strength and chromaticity (x) of H_2SO_4

VI. CONCLUSION

- Immersion in hydrochloric acid (HCl) and sulfuric acid (H_2SO_4) led to significant reductions in compressive strength of 23.53% and 27.97%, respectively, after 56 days. In contrast, sodium chloride (NaCl) and acetic acid (CH_3COOH) resulted in milder reductions of 7.54% and 8.19%, indicating greater durability in NaCl and CH_3COOH environments.
- The mode values derived from RGB color histograms, based on rectangular or polygonal region selections, most accurately capture the color features of surface damage. In contrast, mean RGB histogram values from randomly chosen pixels were used for validation.
- Chromaticity (CIE-XYZ) analysis shows that HCl causes a red shift, H_2SO_4 shifts color towards white, while NaCl and CH_3COOH cause minimal changes. Sulfuric acid has the greatest negative impact on concrete strength, acetic acid improves it up to an optimal point before decreasing, and NaCl is most effective within a specific concentration range. Optimal chromaticity correlates with maximum compressive strength.
- Color profile changes in samples immersed in HCl, NaCl, H_2SO_4, and CH_3COOH exhibit similar patterns, but the extent of deterioration differs. Sulfuric acid caused significant white salt deposition, hydrochloric acid resulted in delamination, while NaCl and acetic acid produced localized white patches due to leaching.

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REFFERENCES

1. Banerjee, A., Guru Prathap Reddy, V., Pancharathi, R. K., & Tadepalli, T. (2022). A novel method for deterioration assessment in concrete using colorimetry analysis. Magazine of Concrete Research. https://doi.org/10.1680/jmacr.21.00071.
2. Guru Prathap Reddy, V., Tadepalli, T., & Pancharathi, R. K. (2022)Non-destructive evaluation of concrete deterioration through surface imaging using the hue-saturation-intensity color space. Measurement, 197,111311.
3. Sarıcı, D. E. (2016). Thermal deterioration of marbles: Gloss, color changes. Construction and Building Materials, 102, 416–421. https://doi.org/10.1016/j.conbuildmat.2015.10.189.
4. Karaman, S., Gunal, H., & Ersahin, S. (2006). Assessment of clay bricks compressive strength using quantitative values of colour components. Construction and Building Materials, 20(5), 348–354. https://doi.org/10.1016/j.conbuildmat.2004.11.006.
5. Banerjee, A., Guru Prathap Reddy, V., Pancharathi, R. K., & Tadepalli, T. (2022). Colour-stability analysis for estimation of deterioration in concrete due to chemical attack. Construction and Building Materials, 321, 126288. https://doi.org/10.1016/j.conbuildmat.2022.126288.
6. Gökay, M. K., & Gundogdu, I. B. (2008). Color identification of some Turkish marbles. Construction and Building Materials, 22(7), 1342–1349. https://doi.org/10.1016/j.conbuildmat.2007.04.009
7. Annerel, E., & Taerwe, L. (2011). Methods to quantify the colour development of concrete exposed to fire. Construction and Building Materials, 25(9), 3989–3997. https://doi.org/10.1016/j.conbuildmat.2011.04.047.
8. López, A., Guzmán, G. A., & Di Sarli, A. R. (2016). Color stability in mortars and concretes. Part 2: Study on architectural concretes. Construction and Building Materials, 123, 248–253. https://doi.org/10.1016/j.conbuildmat.2016.06.128.
9. IS 12269:2013 – Bureau of Indian Standards. (2013). Ordinary Portland Cement, 53 Grade – Specification. New Delhi: BIS.
10. IS 383:2016 – Bureau of Indian Standards. (2016). Specifications for Coarse and Fine Aggregates in Concrete. New Delhi:BIS.
11. ASTM C494/C494M-15 – ASTM International. (2015). Standard Specification for Chemical Admixtures for Concrete. West Conshohocken, PA: ASTM International.
12. IS 10500:2012 – Bureau of Indian Standards. (2012). Drinking Water – Specification. New Delhi: BIS.
13. IS 265:1993 – Bureau of Indian Standards. (1993). Specification for Acetic Acid. New Delhi: BIS.
14. IS 797:1982 – Bureau of Indian Standards. (1982). Specification for Sodium Chloride. New Delhi: BIS.
15. IS 265:1993 – Bureau of Indian Standards. (1993). Specification for Hydrochloric Acid. New Delhi: BIS.
16. IS 10262:2019 – Bureau of Indian Standards. (2019). Concrete Mix Proportioning – Guidelines. New Delhi: BIS.

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