Durability Analysis of Concrete made from PPC and OPC 43 using Half-cell Potentiometer

Yasir Karim [1]
Rishabh Jain[2], Mregaakshi[2], Krashank[2], Harshit Kumar dev[2], Jai singh[2], Pulkit Shrivastav[2]
[1] Supervisor, Assistant Professor, Department of Civil Engineering, **KIET Group of Institutions**, Delhi-NCR, Ghaziabad
[2]Undergraduate Scholars, Department of Civil Engineering, **KIET Group of Institutions**, Delhi-NCR, Ghaziabad

ABSTRACT
Steel corrosion is an important factor in the degradation of reinforced concrete buildings. ASTM C 876-91 is a standard test method that can be used in both field and laboratory settings to measure the half-cell potentials of uncoated reinforcing steel in concrete. This measurement can help determine the level of corrosion activity in the steel. By using electrical circuitry and potential difference, this test method can provide insight into the rate of corrosion and the overall durability of reinforced concrete.
As per this research, we focus to evaluate the impact of acid exposure in the durability of the reinforced concrete (RCC) through experimental analysis. Our approach involves the preparation of concrete cubes with dimensions of 70.5mm x 70.5mm x 70.5mm using M30 grade concrete as per the mix design. A total of 24 cubes are cast for testing purposes. To initiate the experimentation, these cubes are initially cured by immersing them in water for a period of 28 days. Subsequently, the cured cubes are subjected to immersion and spraying with various concentrations of acids, namely hydrochloric acid, sulfuric acid, and sodium chloride, each at a 3% concentration. This exposure lasts for 56 days, allowing for the evaluation of the effects of acid exposure on the durability of the RCC structures. To determine the durability of the RCC structure, the cured cubes are tested using a Half-Cell Potentiometer apparatus. This apparatus measures the potential differences and provides insights into the corrosion resistance of the concrete. A comparative analysis is conducted between concrete made from Portland Pozzolanic Cement (PPC) and Ordinary Portland Cement (OPC) of Grade 43(both).
Based on our findings, it is evident that the PPC-made concrete exhibits higher durability and superior resistance against corrosion compared to concrete made with OPC. This research underscores the importance of durability and highlights the significant role of various factors such as hydrochloric acid, sulfuric acid, sodium chloride, and corrosion.
Keywords: *Durability, Hydrochloric acid, Sulphuric acid, Sodium Chloride, Corrosion*

1. INTRODUCTION

According to ASTM E632 from 1996, concrete durability is the ability of a structure to survive the design environment for the duration of its intended service life without experiencing a substantial loss in usability or needing major repair and maintenance. Concrete deterioration typically results from the penetration of aggressive agents from the environment that react with the matrix. Other sources of deterioration may occur internally, such as alkali-aggregate reaction (AAR) or delayed ettringite formation.

Steel corrosion is an important factor in the degradation of reinforced concrete buildings. Concrete's pore solution acts as an electrolyte in the electrochemical process that results in cathodic and anodic zones forming on steel surfaces as a result of variations in electro-galvanic potential. The anodic chemical reaction, cathodic chemical reaction, and ionic current flow are the three processes that contribute to the pace at which the electrochemical process happens.

American standard testing machine C 876-91 is a standard test method that can be used in both field and laboratory settings to measure the half-cell potentials or potential difference of uncoated reinforcing steel in concrete. This evaluated results can help determine the level of corrosion activity in the steel. By using electrical circuitry and potential difference, this test method can provide insight into the rate of corrosion and the overall durability of reinforced concrete.

1.1 Objectives

To fulfil the goal of this study, the aforementioned goals are suggested:

i. A thorough review of the literature on chemical attacks on materials, particularly acids on concrete.
ii. Through experimental research, assessment of the effect of acids on the compressive strength of concrete.
iii. Investigating how an acid assault on concrete affects it by changing the following factors:
    - Time of attack
    - Acid Concentration
    - Acid Kind
    - Attack technique

1.2 Studying acid attacks on concrete structures is necessary.

To fulfil the goal of this study, the aforementioned goals are suggested:

i. Acid spills on concrete floors in battery storage plants, sulfuric acid attacks in sewer pipes, and industrial effluents running through concrete channels are just a few examples.

ii. Food processing businesses, chemical laboratories, paint manufacturing businesses, and fertilizer storage and manufacturing businesses round out the list.

2. LITERATURE REVIEW

JOURNAL DESCRIPTION	RESULTS/FINDINGS	AUTHOR
1. An electrochemical analysis of the effect of sulphates on steel bar corrosion caused by chloride in cement-based materials	Steel bar corrosion in concrete is accelerated by the presence of sulphates in a chloride environment.	A F Abubakar et al, Vol. 9, No. 2, PP.112–126,
2. Concrete reinforcement corrosion caused by fly ash and manufactured sand	The rate of corrosion is 20% > 40% > 30%. In all exposed conditions, 30% fly ash replacement samples exhibit less corrosion than 40%.	J. Mahesh et al, VOL. 23, NO. 7, PP. 413–421,
3. 3. Research into the effects of rice husk ash on reinforced concrete's compressive strength, carbonation, and corrosion resistance	The potential tends towards more positive values as RHA percentage increases, showing that the corrosion potential is almost non-existent. In light of the half-cell potential values, RHA are competent in corrosion resistance.	Nahida Nisar et al, VOL. 19, NO. 2, PP.155–163,
4. The impact of fly ash on the resilience of concrete to freeze-thaw in a marine environment	Due to the pozzolanic activity of fly ashes, which produces more calcium silicate hydrate (C-S-H) gel and fills pore spaces, fly ash concrete has superior resistance to freeze-thaw deterioration and can effectively reduce corrosion of the embedded steel reinforcement.	Md. M. Islam et al, Vol. 19, no. 2, PP.146–161,

3. LABORATORY/EXPERIMENTAL WORK

Mix design of M 30 grade Concrete done by two types of cement OPC and PPC as per IS 10262:2019.

Mix Design M-30 Grade					
S.no.	Cement Type	Components	**In SSD Condition**	**In Dry Condition**	Remark's
1	**OPC**	Cement	393 Kg/m3	393 Kg/m3	
2		Water	165 Kg/m3	188 Kg/m3	
3		Fine Aggregate	829 Kg/m3	812 Kg/m3	
4		Coarse Aggregate	984 Kg/m3	978 Kg/m3	
5		Super-Plasticizer	3.93 Kg/m3	3.93 Kg/m3	
6		Water-Cement Ratio	0.42	0.42	

Table 1: Mix design of OPC

Mix Design for M-30 Grade					
S.no.	Cement Type	Components	**In SSD Condition**	**In Dry Condition**	Remark's
1	**PPC**	Cement	393 Kg/m3	393 Kg/m3	
2		Water	165 Kg/m3	188 Kg/m3	
3		Fine Aggregate	829 Kg/m3	812 Kg/m3	
4		Coarse Aggregate	984 Kg/m3	978 Kg/m3	
5		Super-Plasticizer	3.93 Kg/m3	3.93 Kg/m3	
6		Water-Cement Ratio	0.42	0.42	

Table 2: Mix design of PPC

3.1 Compressive Strength Test:

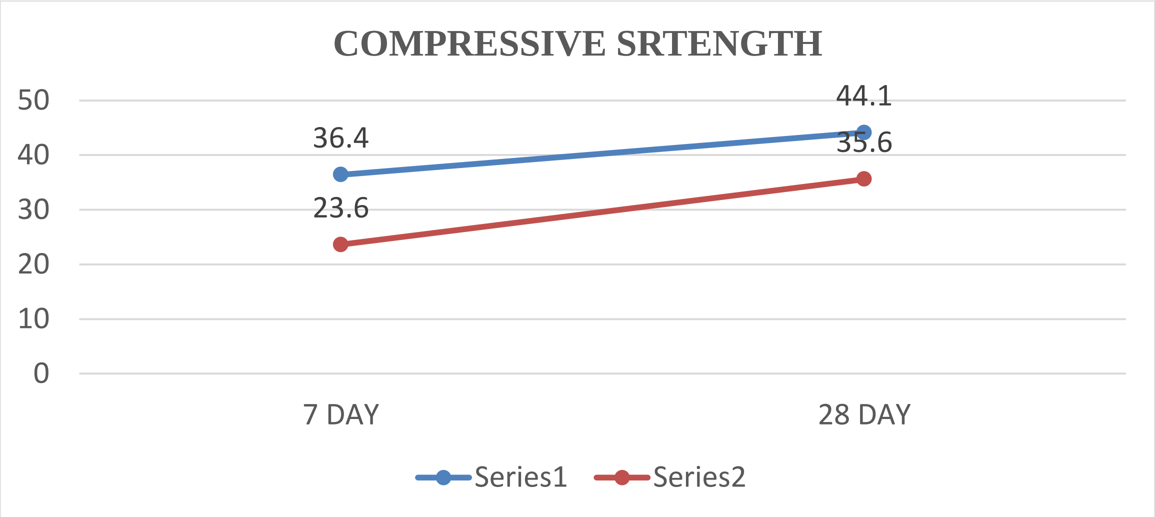
Cube size: 70.6 x 70.6 x 70.6mm
No. of samples PPC = 06 no’s
OPC = 06 no’s

Table 3: Compressive Strength Test of cubes after 7-Days

Compressive Strength Test after 7-Days				
S.no.	Cubes	**PPC (MPa)**	**OPC (MPa)**	Remark's
1	Sample-1	23.1	35.6	
2	Sample-2	24.2	38.7	
3	Sample-3	23.6	34.8	
	Average	**23.6**	**36.4**	

Table 4: Compressive Strength Test of cubes after 28-Days

Compressive Strength Test after 28-Days				
S.no.	Cubes	**PPC (MPa)**	**OPC (MPa)**	Remark's
1	Sample-1	34.5	42.5	
2	Sample-2	35.6	45.6	
3	Sample-3	36.8	44.3	
	Average	**35.6**	**44.1**	



The above specified materials and mix design will be used to create concrete cube specimens that are 70.5 mm x 70.5 mm x 70.5 mm in size and include embedded MS steel bars. A total of 24 cubes will be cast, and they will then undergo a 28-day curing process in potable water. The hardened concrete cubes will be partially submerged in acid solutions with different concentrations after the initial curing phase. The water-cured specimens will be taken out of the curing environment and allowed to dry in the shade in order to continue the experiment.

The details of the experimental procedure are summarized as follows, ensuring a systematic approach to the investigation: -

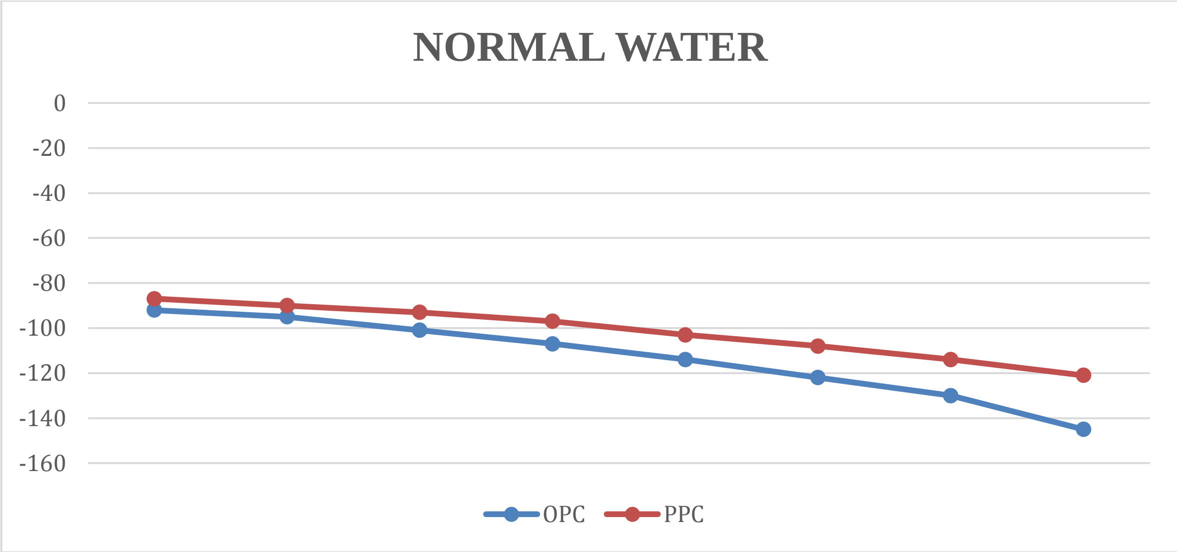
Table 5: Details of Experimentation

Partially submergence of cubes in Solution				
s.no.	Curing Time	Kind of Solution	% of Acid used	Number of cubes
1		Sodium Chloride **(NACL)**	3	6
2	56 Days	Hydrochloric Acid **(HCL)**	3	6
3		Sulphuric Acid **(H_2SO_4)**	3	6

3.2 Observations

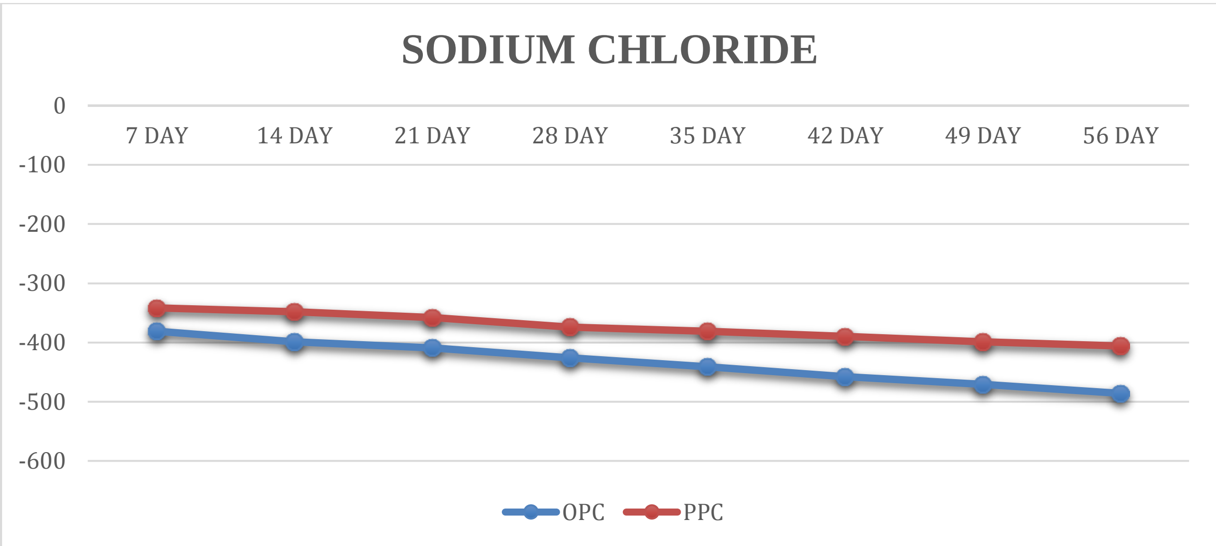
Cubes Partially immersed in 3% HCL, H_2SO_4, NACL for 56 days

Effects of HCL, H_2SO_4, NACL on RCC cubes after 56 Days



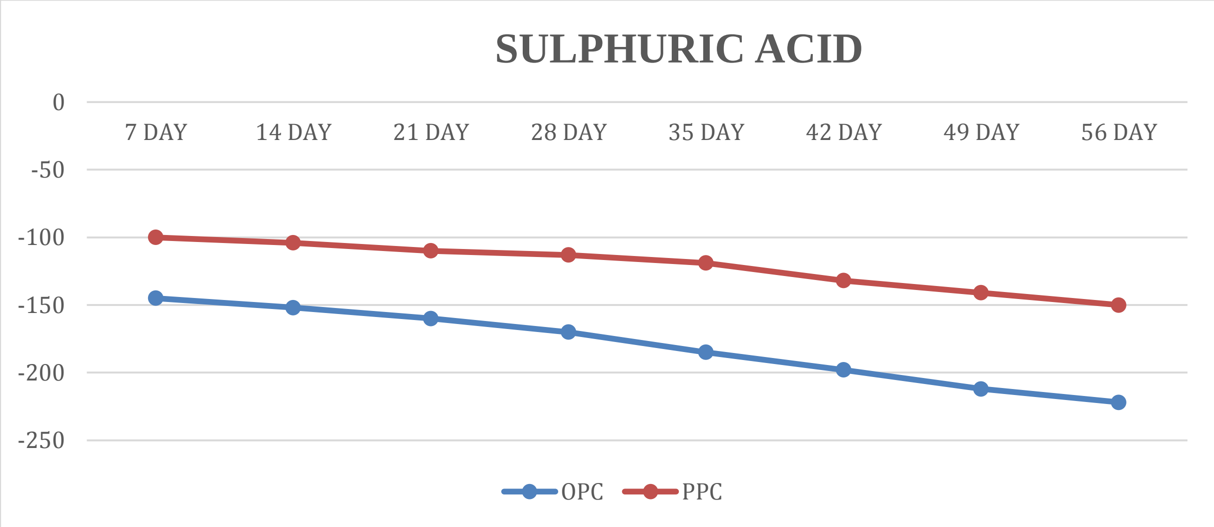
Graph-1: Effects of Normal water on RCC Cubes

- Above data represents rate of corrosion is higher in OPC in comparison to PPC hence we can say PPC is more durable then OPC.



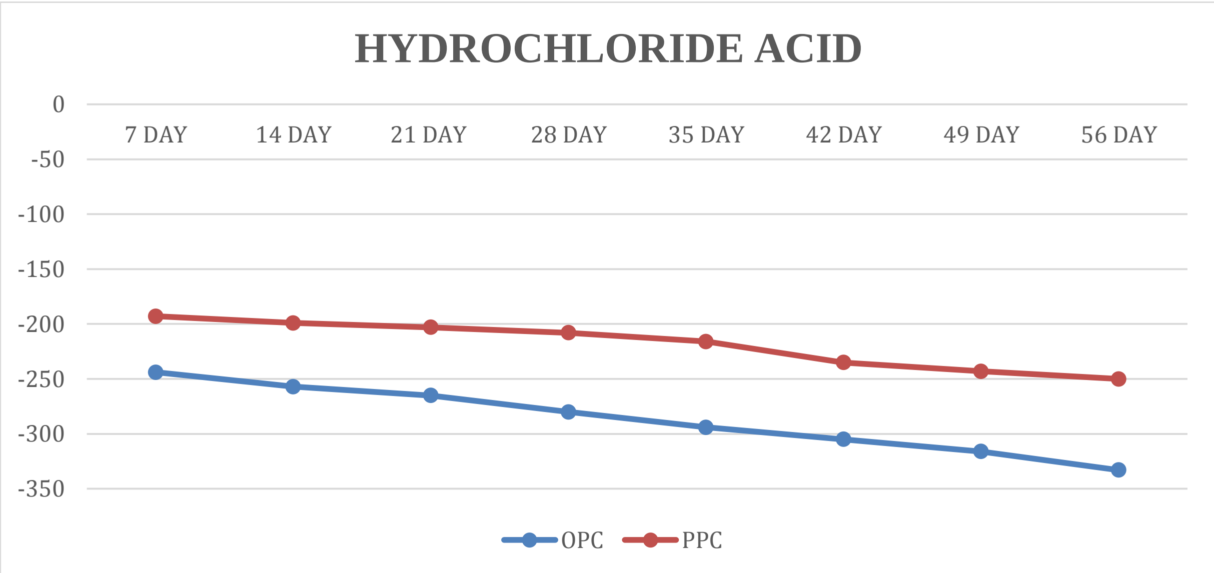
Graph-2: Effects of Sodium Chloride on RCC Cubes

- NACL Affects reinforcement bar sharply and shows less variation in cement concrete, rate of corrosion in NACL condition is increasing rapidly as compare to different conditions like Sulphuric acid and Hydrochloric acid.



Graph-3: Effects of Sulphuric acid on RCC Cubes

- Sulphuric acid attacks cement concrete harshly not and rate of corrosion is less in reinforcement bar but texture affected solely.



Graph-4: Effects of Hydrochloride acid on RCC Cubes

- Hydrochloric acid affects cement concrete and reinforcement at similar rate of variation as per critically seen by naked eyes.

4. CONCLUSION

- The Half-cell Potentiometer Testing Method is a widely used method for assessing the durability of reinforced concrete structures and making it easier to spot reinforcement corrosion. Typically, a negative potential reading is indicative of a higher probability of corrosion occurrence. This method plays a crucial role in assessing the corrosion potential and aids in diagnosing the extent of deterioration in reinforced concrete.

- In case study of PPC and OPC in normal conditions shows that PPC is less prone to corrosion as compared to OPC.
- Throughout the period of two months PPC Shows its fair applications under different environmental conditions.
- After comparing different conditions like in salty (sodium chloride) condition, acidic
  conditions (sulphuric acid and hydrochloric acid) the results shows that sodium chloride causes corrosion by affecting reinforcement bars without showing high variations in the cement concrete in both PPC and OPC.
- In the case of sulphuric acid rate of corrosion is less since it affects cement concrete adversely and slow gradual variations in reinforcement.
- In hydrochloric acid both concrete and reinforcement get affected with similar variations.
- Rate of corrosion sodium chloride>hydrochloric acid>sulphuric acid>normal environmental conditions.
- As per the study and testing it is concluded that PPC is highly durable than OPC in
- **REFRENCES**

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