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Durability Evaluation of Normal and High Performance Concrete

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Abstract—*Classification of concrete is often most feasible means for measuring the durability and has become progressively over the past 20 years. The present study is focused on the capability of concrete to improve its durability when the concrete is subjected to the highly aggressive environments. Existing concrete in cold or coastal regions are affected by chloride penetration under the freeze-thaw cycles. This collective deterioration process quickens the damage advancement of concrete and reduces the service life of the structures. In real life the structure may face numerous deterioration contrivances due to environmental factors surrounded by the concrete. An Acid Attack laboratory test method was used for the determination of durability, which provide the results. For evaluating the durability of concrete, to a single contrivance of deterioration, the techniques were economical and appropriate. For determining the durability of concrete the Ordinary Portland Cement was used. Two different concrete were tested: one the M30 grade of concrete and one M60 grade of concrete, to show the influence of water/cement ratio on durability of concrete. The two solutions were used in the acid attack test: one was 5% HCl solution and the other was 5% H_2SO_4 solution. A total of 12 specimens were prepared and were tested for the compressive strength after 7, 14, and 28 days. Based on the results, it was observed that there was a drop of strength after the specimens were put exposed to acid solution curing.*

Keywords*: Ordinary Portland cement, High Performance concrete, Acid Attack, Compressive Strength.*

1. INTRODUCTION

For a long time, concrete was considered to be a very durable material requiring a little or no maintenance. The assumption is largely true, except when it is subjected to highly aggressive environments [1]. Concrete is a multipurpose and generally used in the construction material in the world. There are different limits for the design of concrete. One of the important parameters in the design of concrete is durability. To increase the service life of structure, not only strength is required but durability parameter is also important [1]. Durability of the concrete is defined as ability of the concrete to repel the weathering action, chemical attack, abrasion or any other process of deterioration. Durability is either through the concrete system like binder type, mixing, transportation, aggregates, admixtures, curing, and temperature at the time of curing, or through the assertiveness of the environment like abrasion, leaching, expansion, erosion, cavitation etc. [1]. Most commonly durability of concrete is affected by sulphate attack, chloride attack, carbonation, ASR reaction, freezing and thawing damage. Durability of concrete is fundamentally related to permeability [1].

In real environment concrete structures are exposed to numerous environmental factors acting in a shared and certainly synergistically physical and chemical manner to quicken the destruction procedure, so it is significant to study the chloride resistance of concrete to acquire satisfactory information on concrete durability [1]. The concentration of the hydroxyl ion inside the concrete is largely measured by the concentration of sodium and potassium. The mechanism of expansion of alkali silica reaction can be explained by absorption theory or osmotic pressure theory. In absorption theory, the reticence of pore water and bulge of the alkali silica gel causes expansion, whereas in osmotic pressure theory, there is an inward diffusion of OH^-, Na^+, K^+ and Ca^{2+} from the pores to aggregate surface. The ratio of the Ca^{2+} to the alkali present controls the expansive nature of the concrete [2]. The concrete can be protected against the alkali silica reaction by the use of stumpy alkali content (less than 0.6%), use of chemical admixtures, use of mineral admixtures such as silica fumes, or by applying coatings or water proofing agents. The use of high reactivity metakaolin has the prospective to improve the durability [2]. If the concrete remains frozen, then there will not much problem occurs, but if the cycles of the freezing and thawing repeat again and again, then there will be the existence of deterioration. The internal stress is produced in the concrete, due to the pore solution inside concrete freezes into ice through freezing-thawing process. When the stress is more than that of the strength of concrete, there will be the incidence of the micro-cracks, which will result in interconnecting the flow channels, owing to which there will be more chloride penetration, which result in decrease of durability [2].

Due to antagonistic marine acquaintance environment and wide use de-icing salts, corrosion in the reinforced concrete structure due to the chloride persuaded is most common cause of degradation [3]. In concrete, chlorides can chemically bound with cement C3A or C4AF phases [3]. The degree of diffusion of cl^- ions in concrete increases with increase in temperature [3]. The most unfavourable environment situation for the reinforced concrete is drying and wetting cycles [3]. In carbonation, there is a chemical reaction between portlandite (which is present in hydrated cement) and CO_2. Relative humidity, the concentration of CO_2, penetration pressure and the temperature of the environment where concrete is placed, are the factors on which the degree of carbonation rest on [4]. When using the normal PC, the degree of carbonation is lower [5]. The durability can be increased by using pozzalans material such as fly ash, as it reduces the calcium hydroxide of the cement matrix [6]. Sulphate solution and sulphuric acid solution are both harmful to durability part of concrete. The parameters to which the resistance of concrete to chemical attack depends are, the capability to neutralize the chemical solution, the passivation by the deposition of responded products and the pore structure characteristics [6]. The permeability of concrete is resolved by the pore structure. The corrosion rate can be accelerated, when there is crack present in the concrete because of the decay causing factors can pass past the crack [7]. The protection against the sulphate attack can be done by use of C_3A, as it will reduce the formation of CH. Low w/c ratio can also reduce the sulphate attack. Use of blended cement and high alumina cement can also reduce the sulphate attack in concrete. The presence of crack in the concrete, significantly influence the durability of reinforced concrete structure [7]. In ASR, there is a reaction between alkali (Na^+, K^+), reactive silica and moisture, which results in the formation of alkali-silica reaction gel which expands which results in concrete cracking. Various forms of reactive silica are opal, silica glass, chalcedony, tridymite crystallite and quartz. The use of larger size water glass as an auxiliary of coarse aggregate in concretes have been stated to facilitate the ASR [8]. In relations of the cement conformation, the main compound concerning the sulphate resistance of the cement is C_3A [9]. The sulphate resistance of the low C_3A Portland's cements is largely pretentious by the CH out from the silicates [9]. Carbonates addition have no substantial consequence on sulphate resistance, excluding C_3A dilution, when enormous filler substitutes are used in type 1 Portland cement [9].

2. EXPERIMENTAL PROGRAM

2.1 MATERIALS

All the chemicals and reagents used in the present study were of analytical grade. The cement used was Ordinary Portland Cement (OPC 43) conforming to IS: 8112 – 1989 (ACC Limited, India). A Super Plasticizer "High Range Water Reducing Agent" of Fosrec were procured which is used for the preparation of concrete and testing of concrete.

2.2 METHODOLOGY

The following flow chart represents the different stages:

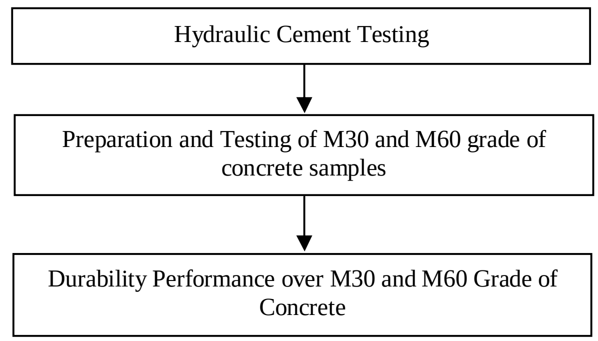

Figure 1: Flow Chart of Plan of this study.

2.2.1 Physical Properties of Cement

Hydraulic Cement required to satisfy its physical properties up to its permissible limit. Hydraulic cement tests were performed to obtained the Physical characteristics of Cement used in the present study. To get the consistency and initial & final setting time of cement Vicat's apparatus used, the plunger penetration gave consistency and initial setting time for cement while the needle impression gave the final setting time of cement. The consistency helps us to find the water requirement for complete hydration of cement. Initial and Final setting time used to elaborate the setting times of cement when it starts to set till its hardening. Le-Chatelier apparatus used to obtained the soundness of the cement which is affected by the presence of free lime. The cement must be fine enough to pass the 90-micron sieve. The specific gravity of cement and all cementitious materials were find out by using Le-Chatelier's bottle. The specific gravity of fine aggregate obtained by using fineness modulus of sand was also done to determine the zone of sand while density bucket used for measure the specific gravity of coarse aggregates. The specific gravity of fine and coarse aggregates along with the cement specific gravity helps us to design the concrete mix. The proportion of mix design for M30 and M60 grade of concrete is shown in Table 1 and Table 2.

Table 1: M30 grade of concrete mix design

Sr. No.	Material	Quantity (kg/m3)
1.	Cement	413
2.	Water	186
3.	Coarse Aggregate	1186.688
4.	Fine Aggregate	674.804

Table 2: M60 grade of concrete mix design

Sr. No.	Material	Quantity (kg/m3)
1.	Cement	500
2.	Water	165.8
3.	Coarse Aggregate	1072.3
4.	Fine Aggregate	660.21
5.	Micro Silica	35
6.	HRWR	0.0096

2.2.2 Sulfate Attack:

The 3 set of concrete cubes of 150 X 150 X 150 mm were casted by manual mixing in the laboratory for M30 and M60 grade of concrete. The cubes were in 2% Na_2SO_4 solution for curing at room temperature. Cubes were tested for compressive strength after 7, 14, & 28 days of curing in solution and tested in compression testing machine.

2.2.3 Chloride attack:

The set of 3 concrete cubes of 150 X 150 X 150 mm were casted by the manual mixing in the laboratory for M30 and M60 grade of concrete. The cubes were kept in 3% NaCl solution for curing at room temperature. The cubes were tested for the compressive strength after 7, 14, & 28 days of curing in chloride solution and testing in compression testing machine at respective days.

2.2.4 Acid Attack Test:

The 3 set of concrete cubes of 150 X 150 X 150 mm were casted by manual mixing in the laboratory for M30 and M60 grade of concrete. The cubes were kept in respective solutions of 5% H_2SO_4, 5% HCL & in solution of 100% H_2O for curing, at room temperature. Cubes were tested for compressive strength after 28 days of curing, tested in compressive testing machine.

2.2.5 Sorptivity Test

It is the test method used to govern the rate of absorption of water by hydraulic cement concretes. It is measured as increase in mass of specimen resulting from the absorption of water, when alternate side is exposed to water. The test for determining the absorption rate follows ASTM C 1585 - 13. The test specimen was 100 mm diameter and with a length of 50 mm. The test specimen should be placed in a sealable container and store the container at 23°C. for at least 15 days. Then remove the specimen from the container after 15 days and record the initial mass of the specimen. Epoxy paint was used for sealing the specimen. And then record the mass of sealed specimen. Then, place the support on the pan and fill with water till it rises up to 1-3 mm, above the top of support device. Then place the test specimen on the supported material and immediately start the timing device. The mass of the specimen was recorded at interval of 60 secs, 5 min, 10 min, 20 min, 30 min, 60 min and every hour up to 6 hr. The absorption rate is calculated by the formula:

$$I = m/ (a \times d)$$

Where;

I = absorption

m = the change in mass of specimen in time t.

a = the specimen exposed area in mm^2

d = density of water in g/mm^3

3. RESULTS AND DISCUSSION:

3.1 Sulfate Attack:

The loss in compressive strength for M30 is 0.45% and for M60 is 0.18%. The comparative graphical representation between sulfate curing and tap water curing of M30 grade of concrete is shown in Figure 2 and similarly of M60 grade of concrete is shown in Figure 3.

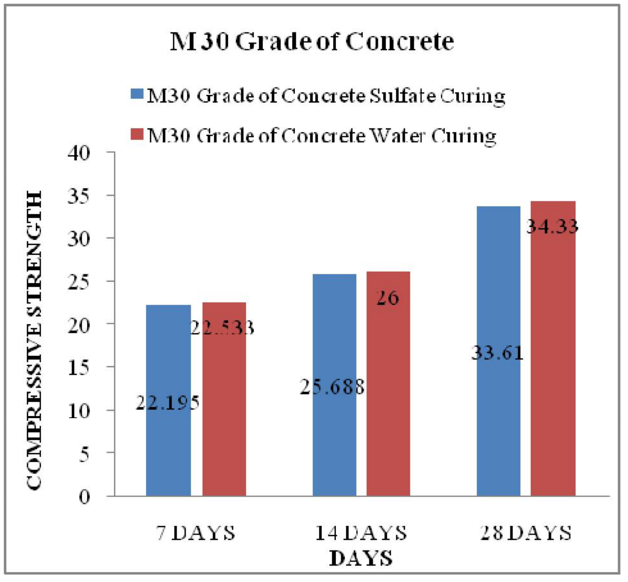

Figure 2: Comparison of Compressive Strength for M30

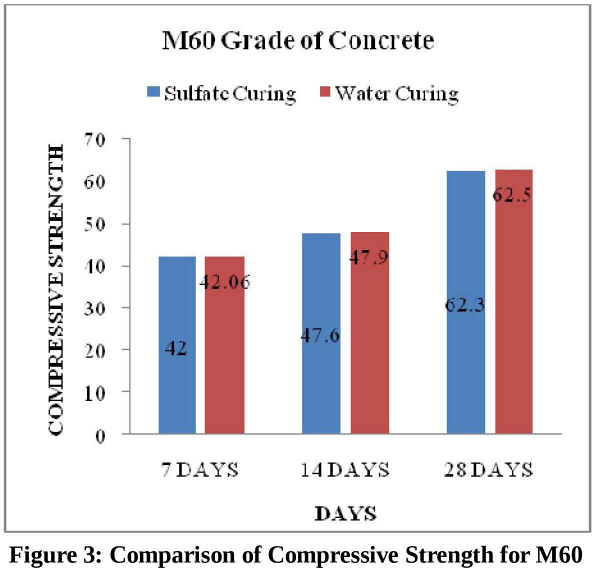

Figure 3: Comparison of Compressive Strength for M60

3.2 Chloride Attack:

The change in compressive strength was compared to the standard samples were 0.567% for M30 and 0.35% for M60. The comparative graphical representation between chloride solution curing and tap water curing of M30 grade of concrete is shown in Figure 4, And similarly of M60 grade of concrete is shown in Figure 5.

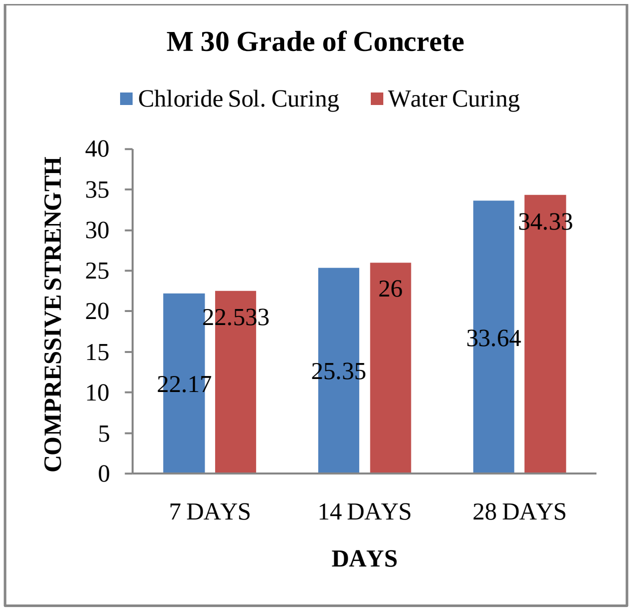

Figure 4: Comparison of Compressive Strength for M30

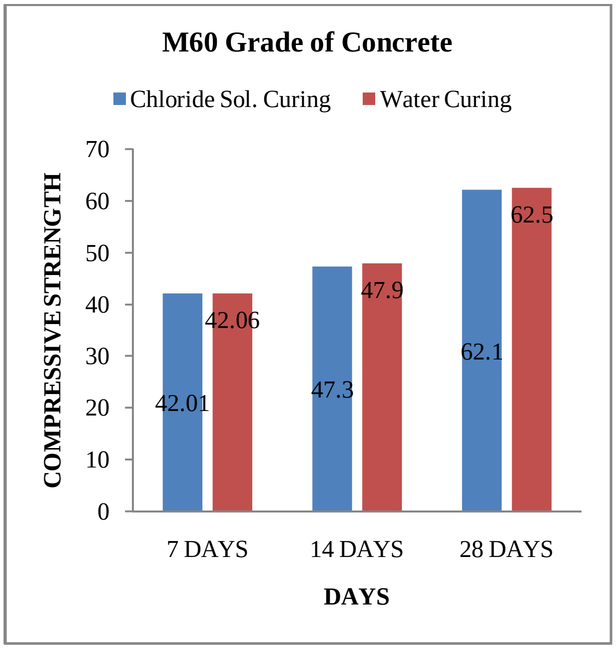

Figure 5: Comparison of Compressive Strength for M60

3.3 Acid Attack:

The effect of acid attack measured by the reduction in compressive strength w.r.t., controlled samples is shown in the graph for M30 and M60 respectively. The comparative graphical representation between 5% HCl solution curing and tap water curing of M30 grade of concrete is shown in Figure 6, And M60 grade of concrete is shown in Figure 7. Similarly, the comparative graphical representation between 5% H_2SO_4 solution curing and tap water curing of M30 grade of concrete is shown in Figure 8, And M60 grade of concrete is shown in Figure 9.

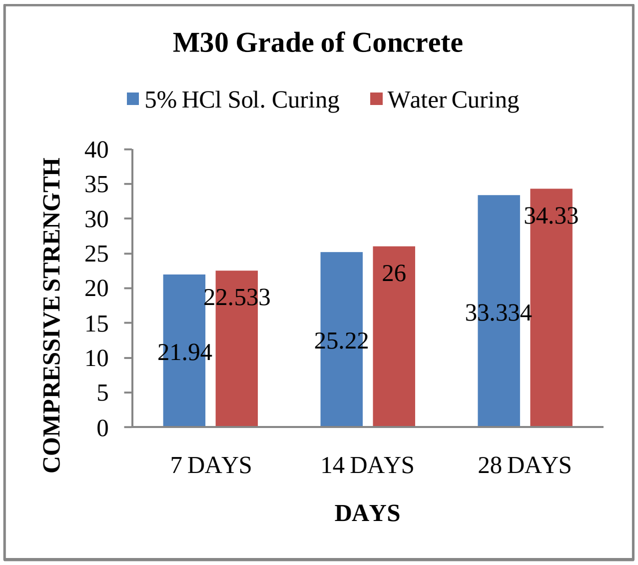

Figure 6: Comparison of Compressive Strength for M30

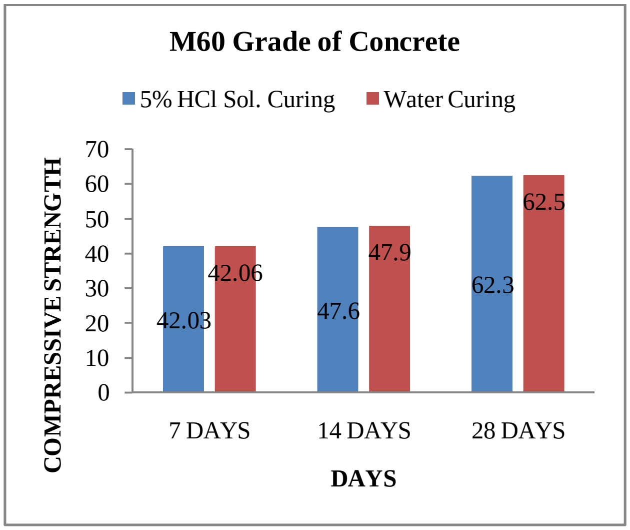

Figure 7: Comparison of Compressive Strength for M60

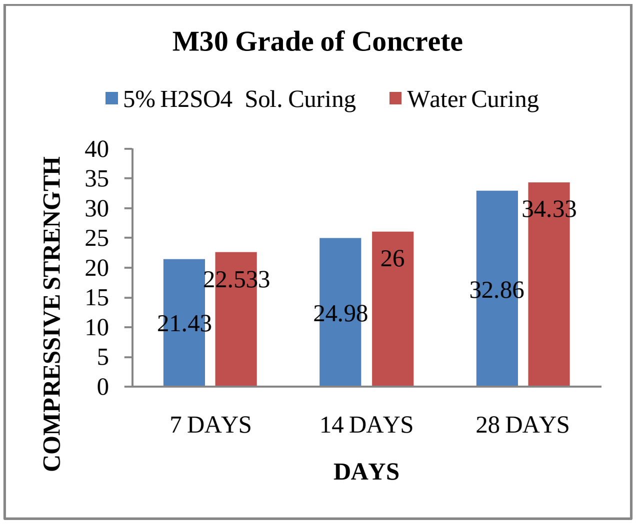

Figure 8: Comparison of Compressive Strength for M30

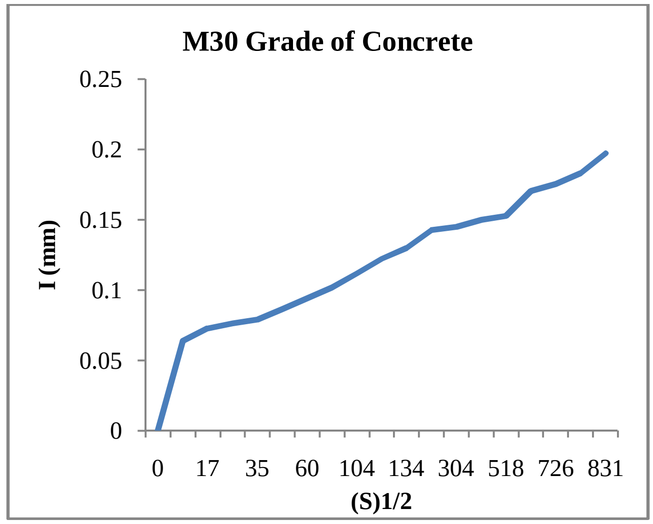

Figure 10: The absorption in M30 Grade of Concrete

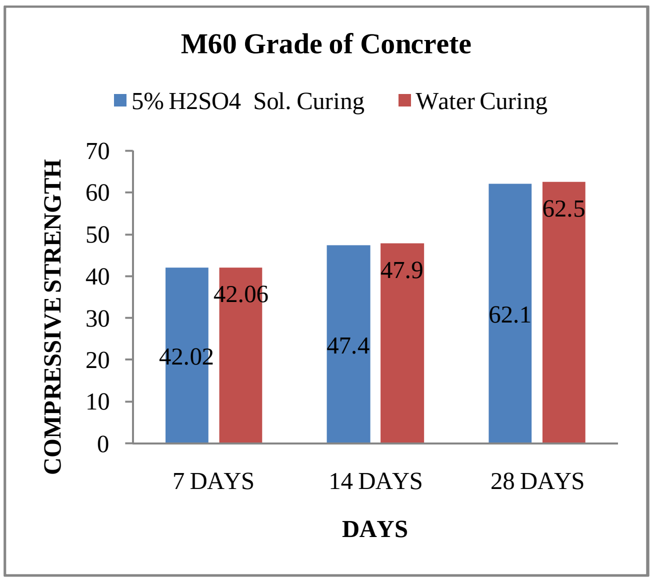

Figure 9: Comparison of Compressive Strength for M60

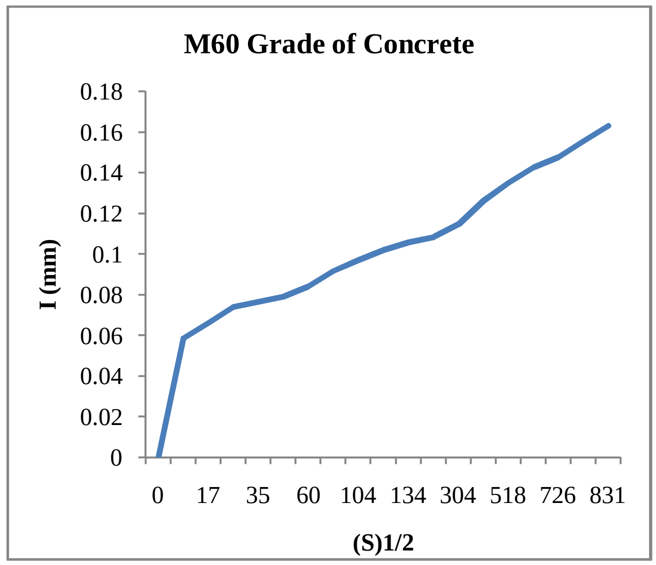

Figure 11: The absorption in M60 Grade of Concrete

Therefore, it was observed that there was drop in the compressive strength when the samples were cured in the 5% HCl solution and 5% H_2SO_4 solution after 7, 14, and 28 days both for M30 and M60 Grade of concrete.

3.4 Sorptivity Test

The maximum absorption in M30 grade of concrete found 0.197352 mm after 8 days' immersion of 100X50 mm core in water. While the maximum absorption in M60 grade of concrete found 0.162974 mm after 8 days of immersion of M60 grade concrete sample. The data for different time duration is shown in the graphical representation as shown in figure 10 and figure 11 respectively for M30 and M60 Grade of concrete.

4. CONCLUSIONS

The sulfate attack, the chloride attack, the acid attack, and the water absorption of M30 and M60 grade of concrete was investigated in this study. The following conclusions can be drawn on the basis of experimental results:

1. Concrete exposed to the sulfate solution shows the loss in compressive strength for M30 is 0.45% and for M60 is 0.18%.
2. Concrete exposed to chloride solution shows the loss in compressive strength for M30 is 0.567% and for M60 is 0.35%.

3. Concrete exposed to acid solution, it was observed that the strength reduction in 5% HCl solution for M30 Grade of concrete is 0.78% and for M60 grade of concrete is 0.17%. While the reduction in compressive strength for 5%H_2SO_4 immersed samples of M30 and M60 grade of concrete were found 1.197% and 0.313% respectively.
4. The maximum absorption in M30 grade of concrete found 0.197352 mm after 8 days' immersion core in water. While the maximum absorption in M60 grade of concrete found 0.162974 mm after 8 days of immersion concrete sample.

5. ACKNOWLEDGEMENT

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