

# Experimental Evaluation of Durability Indices for Medium Strength Concrete Containing Mineral Admixtures

R. R. Parmar<sup>1</sup>, Dr. J. D. Rathod<sup>2</sup>

<sup>1</sup>Assistant Professor, Applied Mechanics and Structural Engineering Department, Faculty of technology and Engineering, M.S. University of Baroda, Vadodara.

<sup>2</sup> Associate Professor, Applied Mechanics and Structural Engineering Department, Faculty of technology and Engineering, M.S. University of Baroda, Vadodara.

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**Abstract** - The aspect of the durability of the concrete was not afforded as much attention as compressive strength. Consequently, many structures have shown signs of deterioration earlier than their expected service life, which has resulted into need for repair and rehabilitation, often at great cost. Durability of concrete is related to the material performance and environment and cannot be thought of as being an inherent property of the concrete. Compressive strength of concrete can not guarantee durability. It is imperative to quantify durability performance of concrete to evaluate service life prediction of reinforced concrete structures. Durability indices for medium strength concrete containing OPC, silica fume and fly ash in binary and ternary blending are evaluated by testing the specimens at 28 days, 56 days and 90 days. Oxygen permeability, water sorptivity and chloride conductivity tests are conducted to evaluate effectiveness of mineral admixtures in enhancing various transport mechanisms. It is observed that macroscopic pore structure of the concrete material plays an important role in durability of the concrete instead of compressive strength. Results show that blending of silica fume and fly ash as a part replacement of OPC improves durability performance which helps to elongate service life of reinforced structures in marine environment.

**Key Words:** Silica Fume, Fly Ash, Sorptivity, Chloride Conductivity, Oxygen Air Permeability.

## 1.INTRODUCTION

Concrete is one of the most important and widely used construction materials. It is a material composed mainly of cement, aggregate and water. Chemical and mineral admixtures are used as supplementary materials to enhance performance. Concrete may consider to be a durable material if properly proportioned, executed in fresh state, cured, and maintained impervious. Reinforced concrete structures are expected to be maintenance-free during their service lives when such concrete is used. However, there are numerous examples of premature deterioration of modern structures.

A durable concrete is one that performs satisfactorily in the working environment under anticipated exposure conditions during its service life. One of the main characteristics influencing the durability of concrete is its permeability to the ingress of water, oxygen, carbon dioxide, chloride, sulphate, and other potentially deleterious substances.

In the last decade, only strength of concrete was considered in the concrete mix proportioning procedure assuming strength of concrete governing all other desirable properties of concrete including durability. It is not entirely true that the stronger concrete is always a durable concrete. In addition to strength of concrete another factors, such as environmental condition (exposure condition), transport mechanisms that involve the ingress of ions or molecules from surrounding liquids and gases into and through the materials are also important consideration for durability [1].

Different countries have different approaches in addressing the issue of reinforced concrete durability. The traditional prescriptive approach adopted by India specifies limiting values for certain material properties (w/c ratio, cement type, cover etc.) depending on environmental conditions and expected service life of the structure without adequately addressing other issues of the concrete qualitatively [2]. Such limiting values may be out-dated as they were framed based on experience after which significant changes have been occurred with the materials used in modern concrete. While the design may place restrictions on values for certain properties, there is often no way of verifying that the construction practices have adhered to these values established by prescriptive approach since they are difficult to measure.

South African approach has gained credit for following a more performance-based approach rather than the traditional prescriptive which provides a rational method to design for durability [3]. The desired acceptable performance criteria of the structure are defined, and the concrete is specified and designed accordingly to meet these criteria. The Durability Indices (DI) approach provides tools to help define the performance criteria [4]. It suggests use of three tests, namely the Oxygen Permeability Index (OPI) test, Chloride Conductivity Index (CCI) test and the Water Sorptivity Index (WSI) test, to characterise and quantify

different mechanisms of deterioration [5]. This approach addresses permeation, migration, and absorption type transport mechanisms through concrete.

This paper aims to address effectiveness of mineral admixture in three grades of medium strength concrete on all these three transport mechanisms by evaluating indices with the help of which durability of concrete is determined.

## 2. EXPERIMENTAL PROGRAMME

53 grade OPC conforming to IS: 12269 – 1987 [6], Silica fume conforming to IS 15388:2003 [7] and processed siliceous pulverized fly ash conforming to IS 3812 (Part 1): 2013 [8] are used as part replacement of cement in concrete. Dosage of Superplasticizer conforming to IS 9103: 1999 [9] is kept as 0.8 to 1% by weight of cement for workability purpose.

Total 9 types of mixes were designed as per IS 10262: 2019 [10]. (1) M30: OPC (2) M40: OPC (3) M50: OPC (4) M30: OPC+10% SF (5) M40: OPC+10% SF (6) M50: OPC+10% SF (7) M30: OPC+20% FA+8% SF (8) M40: OPC+20% FA+8% SF (9) M50: OPC+20% FA+8% SF.

Total 170 numbers of cube specimens of 150 mm x 150 mm x 150 mm were prepared. Core samples of 3 inches diameter were extracted from each cube specimen and three slices of 30 mm thickness were cut from each core to produce three samples for each test. These samples were tested after 28<sup>th</sup>, 56<sup>th</sup> and 90<sup>th</sup> day for oxygen permeability, water sorptivity and chloride conductivity test.

### 2.1 OXYGEN PERMEABILITY TEST

When fluid moves through the pore structure due to externally applied pressure, this phenomenon defined as permeation. The permeability of the concrete depends on the microstructure of the concrete, environmental condition, and permeating fluid. Ballim developed a falling-head permeameter that allowed simple measurement of oven-dried concrete exposed to oxygen under pressure. Figure 1 shows the experimental test set up for the oxygen permeability test. Concrete core samples are initially dried in oven at 50°C followed by exposing to 100±5 kPa pressure. Darcy coefficient of permeability is determined using a logarithmic transformation from the slope of the pressure decay curve. Oxygen permeability index (OPI) is calculated as the negative logarithm of the Darcy coefficient of permeability. Concrete with oxygen permeability index values above 10 may be considered to have excellent impermeability characteristics whilst values from 9.5 to 10 indicate good impermeability and below 9.5 it is considered poor impermeability.



Fig -1: Test set up for Oxygen Permeability

### 2.2 WATER SORPTIVITY TEST

Sorptivity is defined as a measure of the capacity of the medium to absorb or adsorb liquid by capillarity action. Sides of the specimen are coated with the epoxy material to ensure that absorption takes place in one direction only. A linear relationship is observed when the mass of water absorbed is plotted against the square root of time. The sorptivity, S of the concrete is determined from the slope of the straight line produced. Sorptivity value between 10 and 15 is considered as poor concrete, 6 to 10: good concrete and below 5: excellent concrete.



Fig -2: Sample Preparation for Sorptivity Test

### 2.3 CHLORIDE CONDUCTIVITY TEST

Diffusion is the process where fluids or ions move through a porous material under the action of a concentration gradient. Diffusion occurs in partially or fully saturated concrete and is the dominant internal transport mechanism in marine environment. Diffusion rates depend upon temperature, saturation level of concrete, type of diffusant, chemical interactions and inherent diffusibility of the material [11]. Chloride conductivity testing for which test set up is shown in Fig. 3 has been found to be sensitive to changes in concrete microstructure caused by w/c ratio, initial curing, and type of binder. The type of cementitious material has a significant effect on chloride conductivity. If the chloride value falls below 0.75 mS/cm, it is considered to have an excellent chloride resistance. If it falls between 0.75 and 1.5, it has good chloride resistance and above 1.5, it is considered to be poor chloride resistance.

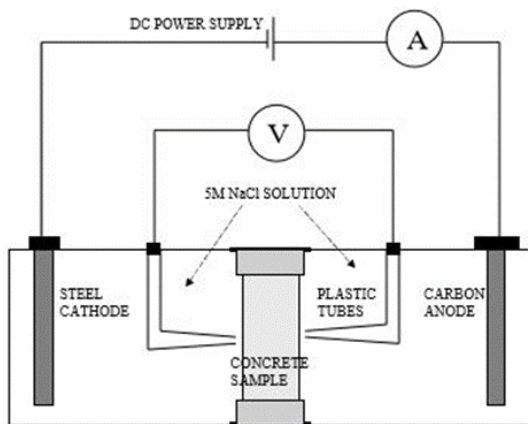


Fig -3: Test set up for Chloride Conductivity Test

## 3. TEST RESULTS AND DISCUSSIONS

### 3.1 OXYGEN PERMEABILITY TEST

Test results of oxygen permeability test for 28<sup>th</sup>, 56<sup>th</sup> and 90<sup>th</sup> days are indicated in Fig. 4. It is found that Oxygen Permeability Index (OPI) almost remains same at different ages. Therefore, this index shall be evaluated on 28<sup>th</sup> days which is representing for remaining period as well. There is no much enhancement of value of OPI after 28 days. Test results are ranging from 9.55 to 9.77 for all the mixes which fall in the category of good resistance against permeability. OPI value is found to be the minimum in concrete produced with OPC for each grade which indicates that use of OPC may not be suggested for durability point of view. As the grade of concrete increases, OPI value also increases. Highest values of OPI are found to be in ternary blended concrete in each grade. Therefore, ternary blended concrete proves to be the best for durable performance. Binary blended concrete i.e., OPC+SF indicate OPI less than ternary blended concrete. It is

to be noted that compressive strength of concrete remains almost same on plain, binary, and ternary blended concrete, whereas durability performance is improvised much when pozzolanic materials are used which is attributed to improvised pore structure, elimination of delayed ettringite formation, pozzolanic reactivity, increased denseness, and enhanced workability etc. Impermeability of concrete is the secret behind durable performance of concrete which is obtained using mineral admixture.

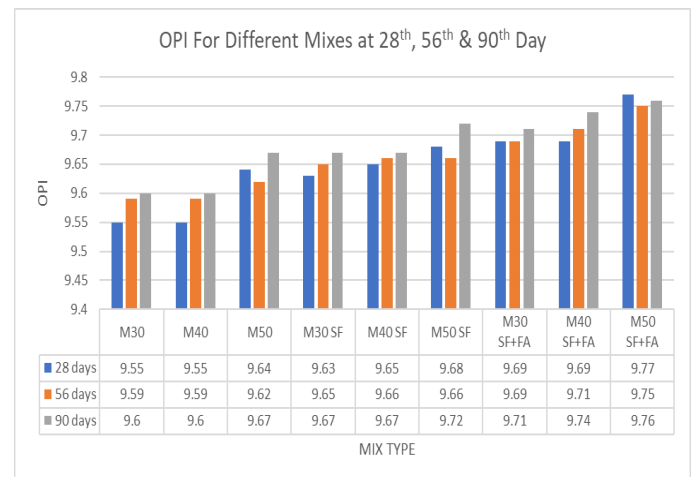


Fig -4 Oxygen Permeability Index for Different Concrete Mixes

### 3.2 WATER SORPTIVITY TEST

Fig. 5 reveals that test results for 28<sup>th</sup> day's exhibit satisfactory Water Sorptivity Index (WSI) index almost for all the mixes may be because of saturation of capillary pores by water. WSI index is found to be the maximum at 59 days for almost all mixes. Effect of addition of mineral admixtures has not been proved to be efficient in reduction of WSI index. It can be said that mineral admixtures do not play any role in absorption phenomenon.

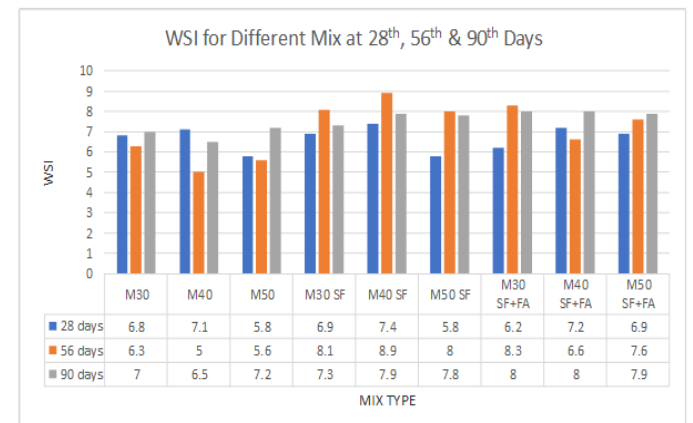


Fig -5 Water Sorptivity Index for Different Concrete Mixes

### 3.3 CHLORIDE CONDUCTIVITY TEST

Fig. 6 reveals that Chloride Conductivity Index (CCI) value decreases with the age of concrete. However, CCI value indicates good performance of all the mixes at 28<sup>th</sup> days. As the grade of concrete increases, CCI index decreases marginally, therefore, imperviousness is enhanced by increasing compressive strength of concrete. CCI index goes on improving when mineral admixtures are used in binary and ternary mixes of all grades of concrete. Diffusion process is affected by addition of mineral admixtures in concrete. Ternary blended concrete mixes exhibit excellent chloride diffusion resistance being value less than 0.75 at 90 days. Blend of silica fume and fly ash is considered to be the most effective resistance against chloride diffusion.

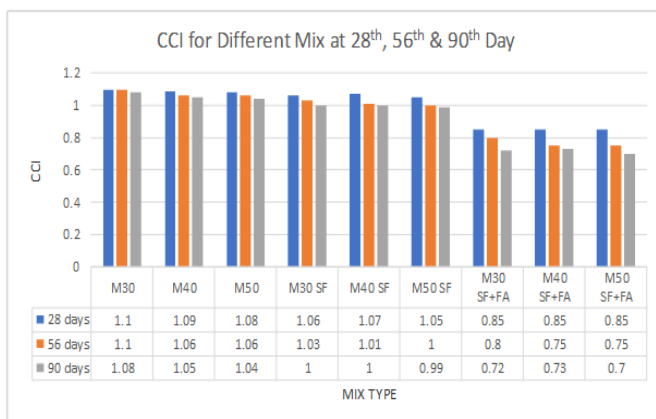


Fig-6 Chloride Conductivity Index for Different Concrete Mixes

### 4. CONCLUSIONS

OPI value increases marginally with increase in compressive strength of concrete as well as increase in age. Addition of mineral admixtures enhances permeation process in concrete as it is improvised in binary and ternary blended concrete. Combination of fly ash and silica fume with OPC in concrete results into the maximum enhancement of OPI value.

WSI value increases with age of concrete may be because of drying the capillary pores. Water sorption property improves with increase in grade of concrete being dense and impervious due lower water/cement ratio. Addition of mineral admixtures does not affect permeation process due to which binary and ternary blended mixes do not exhibit better performance as compared to OPC concrete.

Chloride conductivity of concrete is a resistance against diffusivity. Ternary blended concrete mixes with combination of fly ash and silica fume exhibit excellent chloride diffusion resistance. Therefore, this kind of combination of mineral admixtures in concrete is to be used

under exposure of marine environment which enhances durability of concrete to the large extent.

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### BIOGRAPHIES



**Rajdeep R. Parmar** - B.E. (Civil) M.E. (Structural Engineering), is working as a temporary assistant professor in Applied Mechanics Department of Faculty of Technology and Engineering, The M. S. University of Baroda, Vadodara, (Gujarat), India.



**Dr. J. D. Rathod** is working as an Associate Professor in Applied Mechanics Department of Faculty of Technology and Engineering, The M. S. University of Baroda, Vadodara, (Gujarat), India. He received his Ph. D in 2009 from the same university. His area of interest is on development of Engineered Cementitious Composites and Concrete Technology.