Electrical Properties Of Concrete Used For Various Construction Work - a Comparative Study

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Abstract-Concrete is mostly used as a construction material in world wide and it has been proved that concrete is a multifunctional and smart material, which has an extensive application prospect. This literary study on the basis of comparative study of electrical properties of concrete which are necessary for various construction work. The electrical properties of concrete are electrical conductivity, dielectric, magnetic and insulating properties of concrete are investigate for ease of construction activities. This comparative study also present the factors which are affecting the electrical properties of concrete and also the application of measured properties on the behaviour of various parameters of concrete. The main construction parameters such as safety, durability, and reliability of concrete mostly depends upon the micro-structure, like Porosity that is pore size distribution and tortuosity. This review paper study about the effect of curing time, water cement ratio (w/c), concrete compression strength and moisture content on the basic and electrical properties of concrete. When the tortuosity (inter-connectivity) of pore structure in concrete is fail then it leads to cracking pattern in concrete. Hence it results in the conductivity of concrete significantly inverse to the resistivity of concrete. Hence electrical properties of concrete should be studied for various construction activities. There are many effective techniques have been developed and studied for measurement of electrical properties of concrete. In this comparative study, different approaches in the measurement of concrete electrical resistivity or conductivity are discussed. The correlations between the resistivity measurement and durability, safety, reliability of concrete are reviewed

Keywords* — *Conductivity, Dielectric, Compression Strength, Porosity, Curing, Water Cement ratio of concrete.

I. INTRODUCTION

Concrete is worlds commonly used and versatile building material. The concrete is made up of mixture of cement, sand and aggregates. The concrete block is basically made up of cement , sand , coarse and fine aggregate. The concrete block generally used as a building material in the various construction work like wall and foundations. It is an precast concrete product that means the block is formed and hardened before they are brought to the job site. There is crucial perspective to understand the need of concrete block as a material, because of rapid growth and deterioration of infrastructures. It is therefore need to understand the comparative electrical properties of concrete for durability and various construction work. The concrete is made up of adding water to a mixture of cement, sand and coarse aggregates as soon as the water add to the mix the hydration reaction take place between water and cement. The matrix forms it leads to the compressive strength. The strength of concrete is depends upon the mass ratios of constituent material, water/cement ratio, the cement/sand/aggregate ratio and cement to the total aggregate ratio. The important electrical property is durability of concrete; which is defined as safety and serviceability of the material in harsh environment, it is an ability of material to withstand against the atmospheric action, various chemical attack, abrasion or any other deterioration process to retains in its original form without collapsing [1]. It is commonly accepted that concrete durability is governed by its resistance to the penetration of the aggressive media. The aggressive media may be liquid state or gaseous state. The agressive media is penetrated by various mechanisms such as permeation, diffusion, absorption, capillary action, or combination of mentioned items. There is adverse effect of penetration of aggressive media and durability characteristics. The effect causes carbonation, sulphate attack, alkali-aggregate reaction, soft water attack, acid attack, abrasion, chloride ingress and corrosion of reinforcement. Accordingly the

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transport of ions through the micro structure pores plays crucial role in the less durability of concrete. When ions are charged then the ability of concrete that how it is strongly opposes the flow of electrical charges is commonly known as resistivity of concrete and when it is allow the ion exchange through it is known as electrical conductivity of material. In the mathematical language electrical resistivity defined as it is ratio of the applied potential difference to the current developed. The ratio is multiplied by the constant , known as cell constant. The value obtained is known as resistivity of concrete. The concrete is dielectric and nonmagnetic material. Dielectric material is material whose valance electron shells are nearly full which results as the low conductivity. The concrete dielectric properties are highly influenced by factors like different admixtures, the type of aggregate, water content and curing time [2]. The permittivity is obstruction generated by the material in the formation of electric field, so dielectric constant of the material is ratio of permittivity of substance to the permittivity of free space or vacuum. Moisture penetration and ingress of chlorides are two basic constituent which have the large diverse effect on the dielectric properties of concrete.

II.THEORETICAL BACKGROUND

2.1.Electrical resistivity is tendency of substance to oppose the movement ions to an electrical field. The resistivity depends upon the pore size and microstructure tortuosity [3].The finer pore network results in lower permeability which leads to the higher resistivity [4]. For concrete which is oven dried it varies from 10^6·m [5]. Electrical resistivity is ratio of applied voltage (V) to the resulting current (I) and the ratio multiplied by cell constant [6, 7]. This characteristic is described as follows [3,7]:

$$\rho = k \cdot R = k \cdot \frac{V}{I} \qquad (1)$$

Where, R is concrete resistance, k is geometrical factor (cell constant), V is applied voltage, I is resulting current. There are various factors which are affects the electrical resistivity of concrete, and they care subdivide into two catagories: (1) intrinsic factor and (2) external factor.

The intrinsic factors are nothing but internal factors within the concrete which are responsible for low value of concrete electrical resistivity. The factors are w/c ratio, aging, concrete pore structure. The external factors which are affecting the concrete electrical resistivity are specimen geometry, moisture content, temperature, electrode spacing, in short the more pores and the higher temperature value decreases the resistivity value [6]. Furthermore, adding the reactive cementitious material like fly ash and blast furnace slag which are lowering the permeability values which leads to higher resistivity and lower the conductivity value due to the reduction in capillary porosity.

2.2. Measurement Technique. The resistivity of concrete is measured by several ways in nondestructive manner that means without breaking the concrete block. These methods are typically based on the position of electrode on the specimen surface, or spacing of electrode in linear array or four probe square array on the concrete block surface. There are many devices are used to measure the electrical resistivity of concrete .

2.2.1.Two Point Uniaxial Method (Bulk Electrical Resistivity Test). In the two point uniaxial method, two electrodes are placed parallel on surface of concrete block conventionally two parallel metal plates. The geometrical factor which depends upon the shape and size of specimen obtained by following equation:

$$k = \frac{A}{L} \qquad (2)$$

k = where, A is area of cross section L is the height of sample

2.2.2. Surface Disc Test. In this test a disc which is placed over a rebar, and measuring the resistance in between the disc and rebar it gives the value of resistance [6]. The main disadvantage of this method is the connection needs steel reinforcement and full rebar continuity, discontinuity leads to the less accurate result. In this method, a cell constant depends upon the cover depth which varies with respect to surface and the diameter of rebar whose accurate diameter is not possible due to lack of exact value of current [6]. For depth of cover, disc and diameters is taken at range of 10-50mm, the cell constant is 0.1m. the resistivity is

$$\rho(disk) = 0 \cdot 1 \times R$$

2.2.3. Wenner Four –Point Line array test. In this method as like two point method four electrodes are placed parallel which are used to determine the concrete resistivity value, as shown in figure1. In this technique, two interior probes gives the electrical potential value and another side exterior electrodes apply an AC current to the concrete [8]. For the semi infinite material the cell constant is given by [3],

$$k = \gamma \cdot a \qquad (3)$$

Where a is distance between the electrode which are equal distance and γ is equal to 2π for concrete slab [3]. AASTHO TP 95-11 is the specified standard which used for the determination of surface electrical resistivity [9]

2.2.4. Four Probe Square Array Test. As like above mentioned method, in this method the electrodes are spacing at same distance but in square manner. The spacing is (50-100mm) [10].

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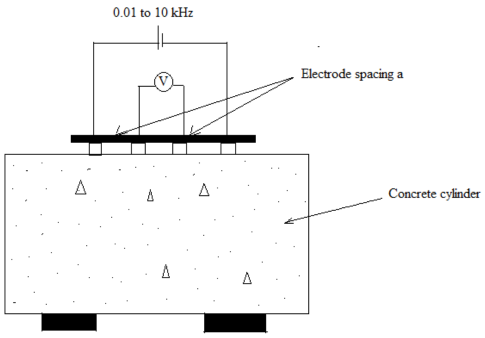

Fig.1. Wenner Four –Point Line array test.

2.3. Dielectric Properties of Concrete. The concrete is dielectric and nonmagnetic material. Dielectric material is material whose valance electron shells are nearly full which results as the low conductivity. The concrete dielectric properties are highly influenced by factors like different admixtures, the type of aggregate, water content and curing time [2]. The concrete dielectric properties including transmission coefficients, reflection coefficient, by using nondestructive technique [11]. The Redheffer [12] suggest the nondestructive and contactless technique for measurement of dielectric properties of material. For measurement of dielectric properties of lot of free space methods were developed [13, 14, 15, 16, 17]. Hence to measure the w/c ratio, strength and moisture content the previous research work shows that there is potential in the use of electromagnetic properties of concrete [18, 19, 20]. As we know that there are many non destructive methods are developed for determination of concrete dielectric properties like: coaxial transmission setup, ultrasonic pulse velocity test, they are used for detecting the chloride ingression in concrete, porosity, homogeneity and strength of concrete. The above methods are laboratory methods for determining the concrete dielectric properties. So the concrete dielectric properties in field is determined by microwave nondestructive technique [11]. The MNDT method gives the value of dielectric constant, loss factor for different w/c ratio.

III. FACTORS AFFECTING THE MEASUREMENT TECHNIQUES

The electrical properties of concrete influenced by pore size distribution, interconnections, conductivity of pore fluid, degree of saturation, temperature, size of aggregate, w/c ratio, type of cement and mix,curing condition, aging of concrete, the contact electrode properties and the alternating current's signal frequency also affects the electrical properties of concrete.

3.1. Effect of Water Cement (w/c) ratio : The permeability of concrete mainly depends upon the percentage of w/c ratio. Higher permeability leads to more voids and more conductance value as result the less resistivity of concrete [21]. The concrete containing different composition shows irregular behavior for various w/c ratio. Within the harden concrete matrix,the electrical conduction flows through the pores media; therefore the concrete electrical resistivity is controlled by interconnected pores.

3.2. Effect of Aggregate Size and Type : In general, the aggregate depends upon their resources and size. The aggregates having more resistivity than the cement paste, due to their shape it contains less porosity and permeability value thus the electrical current can easily flows through hardened cement paste. Increasing aggregate content results in the higher resistivity value. Also the mixture containing 60% aggregate with the size of 16-32mm was approximately 3 times higher than that of cement paste [22].Gravel was rounded shaped aggregates whereas the limestone aggregate having surface texture is rough. Therefore, using rounded gravel aggregates leads to poor bonding with cement paste so that resistivity value decrease.Furthermore, when granite with fly ash increases the resistivity value other than the limestone aggregate type [22].

3.3. Effect of Curing Conditions : The resistivity value of concrete is affected by curing condition [23]. The two major elements influencing the resistivity value they are degree of hydration and the degree of saturation of cementitious material. For a given w/c ratio , it was observed that better curing procedure which yields to the higher resistivity. According to AASHTO TP 95-11 [9], for the sample cured in the lime water tank, the average resistivity value is multiplied by 1.1 for specimen stored in total humid room.

3.4. Effect of Moisture Content : The moisture content is crucial parameter which inversely proportional to the concrete resistivity property, consequently it is directly proportional to conductivity of concrete [24, 25].

3.5 Effect of Electric Properties On the Compressive Strength: The compressive strength is one of the most prominant mechanical property of concrete as the strength point of view. It can be simply measured by the compressive testing machine, which is calculated by load at the time of failure divided by area of specimen [26]. the case of same cementitious material, better correlation is achieved because of relation between compressive strength and permeability [26]. As strength increases, correspondingly the electrical resistivity value increases. So there is directly proportional relationship between these two properties because both are depends upon the porosity of the material.

3.6 Effect of Temperature : The current flow in concrete is due to the ionic movement within the porous network. The ionic movement is influenced by temperature. In general as temperature increases electrical properties like resistivity, dielectric properties increases and conductivity decreases. It

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can be reported as a temperature change of 1℃ which leads to 3% in change in resistivity value of concrete.

IV.APPLICATIONS

The electrical properties of the concrete is used as the equipment of quality assurance for fresh as well as set concrete. This comparative study of electrical properties of concrete leads to the performance characteristics of concrete such as : water absorption, chloride diffusion coefficient, corrosion rate in steel reinforcement.

4.1. Crack Detection : When the inter-relationship of the pore network is broken, the movement of ions are disrupted. Presence of cracks in concrete creates path to flow of ions, hence it gives the flow of current through it hence it leads to electrical conductance of concrete. Therefore electrical conductivity can be used to detect the cracks in concrete. moisture content, setting time measurement

4.2. Setting Time Measurements : The inter-connectivity of the pore network in fresh concrete is enhanced by the addition of water. As the concrete becomes harden, the evaporation of water dries off which leads to the drift in the conductivity can be used to measure the setting time of cementitious material.

4.3. Moisture Content : The resistivity of concrete can be used to determine the moisture content in the concrete

V. CONCLUSION

The electrical properties of concrete measurement shows promise as quality assurance and quality control equipment and also performance assessment tool for concrete materials. As a construction point of view concern this electrical properties measurement gives the long term durability, safety and serviceability of concrete. The electrical resistivity is measured by both uniaxial and the wenner probe method gives the feasible results. While the uniaxial method is reliable for concrete sample and for on site evaluation the wenner probe method is feasible. The dielectric method is used to determine the basic and crucial properties of concrete and its strength. On the basis of this comparative study we conclude that concrete is comprehensive and versatile in nature and the measurement of electrical properties of concrete gives the qualitative result than the conventional method. A relationship between the electrical resistivity and diffusion coefficient which is more effective for durability-based quality control of concrete.

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