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Experimental Study of Durability Indices of Recycled Aggregate Concrete Containing Fly Ash: A Review

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Abstract**: *Concrete durability has been defined by the American Concrete Institute as its resistance to weathering action, chemical attack, abrasion and other degradation processes. Durability is the ability to last a long time without significant deterioration. The governing criterion in the design of reinforced concrete structures in the past, and to a large degree in the present, has been the strength requirement. If concrete strength is appropriate, then it is assumed that concrete in the structure is fine, and it is considered that concrete will take care of itself. But it is not likewise. The aspect of the durability of the concrete was not afforded as much attention. Consequently, many structures have shown signs of deterioration earlier than expected of their service life, which has resulted in the need for repair and rehabilitation of these structures, often at great cost. This implies that the durability is related to the material performance and environment and cannot be thought of as being an inherent property of the concrete. Thus, using strength as a guarantee of the concrete durability is not acceptable any longer. 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.*

Keywords**: *Durability of concrete, Durability index test, Oxygen permeability test, Water sorptivity test, Chloride conductivity Test*

I. INTRODUCTION

Concrete is one of the most important and widely used construction materials. It is a composite material composed mainly of cement, aggregate, and water. Often, chemical and mineral admixtures are used as supplementary materials. For a long time, concrete was considered to be very durable material requiring a little or no maintenance. The assumption is largely true, except when it is subjected to highly aggressive environments. In the past, only strength of concrete was considered in the concrete mix design procedure assuming strength of concrete is an all-pervading factor for all other desirable properties of concrete including durability. For the first time, this pious opinion was proved wrong in late 1930's when they found that series of failures of concrete pavements have taken place due to frost attack.

Although compressive strength is a measure of durability to a great extent it is not entirely true that the strong concrete is always a durable concrete. Concrete durability is a subject of major concern in many countries. Numbers of international seminars are held on concrete durability and numerous papers written on failures of concrete structures are discussed and state-of-the-art reports are written and disseminated, regularly. In the recent revision of IS 456 of 2000, one of the major points discussed, deliberated and revised is the durability aspects of concrete, in line with codes of practices of other countries, which have better experiences in dealing with durability of concrete structures.

One of the main reasons for deterioration of concrete in the past is that too much emphasis is placed on concrete compressive strength. As a matter of fact, advancement in concrete technology has been generally on the strength of concrete. It is now recognised that strength of concrete alone is not sufficient, the degree of harshness of the environmental condition to which concrete is exposed over its entire life is equally important. Therefore, both strength and durability have to be considered explicitly at the design stage.

Fly ash is finely divided residue resulting from the combustion of powdered coal. Fly ash is the most widely used pozzolanic material all over the world. In the recent time, the importance and use of fly ash in concrete has grown so much that it has almost become a common ingredient in concrete, particularly for making high strength and high performance concrete. Extensive research has been done all over the world on the benefits that could be accrued in the utilisation of fly ash as a supplementary cementitious material. There are two ways that the fly ash can be used: one way is to intergrind certain percentage of fly ash with cement clinker

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at the factory to produce Portland pozzolana cement (PPC) and the second way is to use the fly ash as an admixture at the time of making concrete at the site of work.

II. LITERATURE REVIEW

Stephen O. Ekolu and Sheena Murugan [9] had done three durability index tests consisting of oxygen permeability, sorptivity and chloride conductivity were used to evaluate the potential influence of four common cements on strength and durability of concrete. Twenty-four concrete mixtures of water-cementratios(w/c's) = 0.4,0.5,0.65 were cast using the different cement types the concretes investigated fall in the range of normal strength, medium strength and high strength concretes. It was found that the marked differences in oxygen permeability and sorptivity results observed. Results show that while concrete resistance to chlorides generally improves with increase in strength, adequately high chloride resistance may not be achieved based on high strength alone, and appropriate incorporation of extenders may be necessary.

F.T. Olorunsogo and N. Padayachee[10] had investigated the performance of concrete manufactured with recycled aggregate (RA) using durability indexes.Durability indexes, such as chloride conductivity, oxygen permeability and water sorptivity, of three different concrete mixes containing 0%, 50% and 100% RA were monitored at ages 3, 7, 28 and 56 days. The results show that durability quality reduced with increase in the quantities of RA included in a mix; however, as expected, the quality improved with the age of curing. At the age of 56 days, increases in index value of a concrete mix made with 100% RA over that made with 100% natural aggregate were 86.5% and 28.8%, respectively, for chloride conductivity and water sorptivity. The corresponding value of oxygen permeability index (OPI) for the same concrete mixes was a reduction of 10.0%. For 50% RA concrete, the reductions in chloride conductivity and water sorptivity indexes at the curing age of 56 days compared to 3 days were 62.7% and 42.7%, respectively. The corresponding figure for OPI was an increase of 37.6%.

P.E. Streicher [2] et al had carried out the research work on the development of a very rapid test that measures the permeability of concrete to chloride ions. Once sample conditioning has been done, up to 20 concrete samples can be tested in an hour using a single conductivity cell. That test involves saturating a concrete sample with a 5 M NaCl solution. Different concrete samples were yield different conductivities primarily because of differences in their pore structure. The measured conductivity was related to the diffusibility ratio as well as to the chloride diffusivity of the concrete. Also, that concluded the chloride conduction test has a sound theoretical basis.

S Zulu and D Allopi[17] had performed three durabilty tests such as chloride conductivity, oxygen permeability and water sorptivity of concrete containing different content of fly ash they concluded following. The increase of fly ash content can still result in concrete mixtures with acceptable compressive strength. The study shows that by increasing the fly ash in the concrete mixtures can result in equally durable concrete as the standard 30% fly ash concrete without compromising the quality of the concrete, as demonstrated in the Oxygen Permeability Index, Sorptivity and Chloride Penetration durability tests.

Omar S. Baghabra [16] et al had studied on the durability of concrete in which plain, silica fume and fly ash cement concrete specimens prepared with varying water to cementitious materials ratio and cementitious materials content were tested for compressive strength, water permeability, chloride permeability, and coefficient of chloride diffusion after 28 days of water curing. The data so developed were statistically analysed to develop correlations between the compressive strength and the selected durability indices of concrete. Very good correlations were noted between the compressive strength and the selected durability indices, particularly chloride permeability and coefficient of chloride diffusion, irrespective of the mix design parameters. However, these correlations were observed to be dependent on the type of cement.

G.Nganga [11] et al had carried out durability index tests such as chloride conductivity, oxygen permeability and water sorptivity and they concluded that the magnitude of variability in test results was dependent on the degree of control exercised in construction. For the pre-cast elements, strict controls were exercised in construction practices which resulted in a considerably lower variability in values for DI compared to those of in situ elements. The DI test was robust as indicated by the low variability in results.

Mike Otieno [15] et al had carried-out the durability index tests on three ground granulated slags (FeMn arc-furnace (GGAS), Corex (GGCS) and blastfurnace (GGBS) slags) of varying chemical composition, and from different sources were used to make concretes using two w/b ratios (0.40 and 0.60) and three slag replacement levels (20%, 35% and 50%). The effect of chemical composition and replacement level of slags on the chloride penetration resistance of the concretes was assessed using the chloride conductivity test. The results showed that the chloride penetration resistance of concrete increases with decreasing w/b ratio and increasing slag replacement level.

B.G. salvoldi [4] et al had studied oxygen permeability of concrete and its relation to carbonation, they concluded that the test results for oxygen permeability and the accelerated carbonation depth data showed the expected variation between the different binders, w/b ratios and increase in carbonation depth with time. The carbonation coefficients obtained from the carbonation depth readings correlated well with the permeability for each of the binders. The approach presented allows the prediction of carbonation depth development based on the environmental exposure, mix design (binder type), and concrete microstructure, where the latter is defined by the oxygen permeability coefficient. That aids in the development of a scientifically sound and rigorous performance based approach for concrete durability.

MG Alexander [13] et al had made Durability Predictions Using Early-Age Durability Index testing for reinforced concrete structures and also, they concluded that Durability Index tests such as oxygen permeability and chloride conductivity were found to be sensitive to material that affect concrete durability. But the tests were also found to produce reasonable predictions of durability performance under a range of environmental conditions. Also, the durability index approach has a sound theoretical basis and sufficiently quick and practical for site use.

Kung'u Githachuri [14] et al described about the study on the durability potential and strength of composite Portland-limestone cement (PLC) concrete mixtures blended with ground granulated blast furnace slag (GGBS) and/or fly ash (FA). Their performance was compared against ordinary Portland cement, plain PLC and Portland-slag cement concrete mixtures. Using the South African Durability Index approach, results indicate reductions in the penetrability of the composite PLC blends compared to the other mixtures. The durability indica-tors are chloride conductivity, gas (oxygen) permeability and water sorptivity. Compressive strength of the composite PLC mixtures containing both GGBS and FA showed competitive performance with the comparative mixtures, but FA blended PLC mixtures had diminished compressive strength values. The paper also presented considerations on the practical implications of using blended PLC concrete mixtures.

III. CONCLUSIONS

Following conclusions were made from literature review.

The durability index approach had a sound theoretical basis and sufficiently quick and practical for use.

The durability characteristics of silica fume and fly ash cement concretes were better than those of plain cement concrete specimens.

The increased amounts of fly ash content with concrete mixtures had acceptable compressive strength.

30% fly ash concrete gave satisfactory result of Oxygen Permeability Index, Sorptivity and Chloride Penetration durability tests.

A high-strength concrete gave similar OPI values and similar sorptivity indices with best durability performance.

Durability Index Tests can predict service life of reinforced concrete structures and estimate durability performance.

The tests were also found to produce reasonable predictions of durability performance under a range of environmental conditions.

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