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Studies on the Mechanical and Durability Properties of Multi Component Blended Concrete

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ABSTRACT - The importance of the various admixtures such as fly ash, silica fume, rice husk ash, calcium nitrate etc., were studied and analyzed. The optimum percentage of admixtures that gave good mechanical and durability properties results based on trial and error method were selected. The mechanical properties of the concrete such as compressive strength, tensile strength, flexural strength etc after 28 days, 56 days 90 days, 120 days and 180 days were determined. The durability properties of the concrete such as permeability, sulphate attack, chloride attack, chemical attack, corrosion studies etc after 28 days, 56 days 90 days, 120 days and 180 days were determined. Then the results obtained were compared with the results of the concrete properties and that of the conventional concrete. It may be finally concluded that by the replacement of the admixtures in the following proportions 15.0% fly ash, 10.0% silica fume, 10.0% rice husk ash and 3.0% calcium nitrate with the binding material cement, the pore structure, strength properties and durability properties of the concrete were significantly improved.

Key Words: Admixtures, fly ash, silica fume, Rice Husk Ash, Segregation, Sulphate attack, Chloride attack, Corrosion.

I. INTRODUCTION

Concrete is the most widely used artificial construction material in the world and it is second to water as the most utilized substance on the planet (Gambhir 2009). A tremendous infrastructure development has taken place in the country (throughout the world) and making of the concrete for higher strengths to cater to the requirements are significant. The concretes are prepared by blending with various admixtures to cater to the advanced needs and requirements. The replacement of admixtures with the cement in the concrete and preparation of the blended concrete have paved the way to make the best use of the available admixtures, mix proportioning and other factors to produce the concrete satisfying the higher performance requirements. The strength, durability and other characteristics of the concrete depend upon the properties of its ingredients, replacement of admixtures with the cement, proportions of mix, method of compaction and other controls during pouring, vibrating and curing thereafter.

1.1 ADMIXTURES

The properties commonly modified are the workability, rate of hydration or setting times, dispersion and air entrainment. The admixture is added in a relatively small quantity. Most of the admixtures are available in liquid form and are added to the concrete at the mixing plant or at the jobsite. Few admixtures such as expansive agents, pigments, accelerators, retarder's pigments, pumping aids etc are used only extremely small amounts and are usually batched by hand from premeasured containers. The efficiency of the admixture depends on various factors which include quality of cement, quantity of cement, water content, slump, mixing time etc.

1.2 Objectives of the Addition of Admixtures

- To improve the workability of the concrete.
- To improve the durability of the concrete.
- To improve the strength of the concrete.

- To reduce the capillary flow of the concrete

1.3 Types of Admixtures

- Water reducing admixtures
- Air entraining admixtures
- Retarding admixtures
- Accelerating admixtures

1.4 Multi Component Blended Concrete

Four different admixtures are added to modify and improve the properties of the concrete to counteract few adverse environments. The admixtures added in this research work are fly ash, silica fume, calcium nitrate and rice husk ash. To obtain necessary data, several cubical concrete specimens, cylindrical concrete specimens and reinforced concrete wharf specimens are prepared and laboratory tests have been performed to determine the various important properties of the concrete. The first chapter gives the details about the introduction, scope of the project and methodology of the research work. The second chapter presents the various literature reviews. The third chapter narrates the details about experimental programs followed in the research work. The fourth chapter gives details about results and discussions of the strength properties of the concrete in detail. The fifth chapter gives details about results and discussions of the durability properties of the concrete in detail. The sixth chapter gives details about conclusion of the research work and scope for the further research.

II. OVER VIEW OF ADMIXTURES

Several researchers have investigated and reported on various properties of the concrete prepared by using different admixtures in various combinations. This chapter presents the available important studies on the various admixtures in influencing the significant properties of the concrete such as compressive strength, tensile strength, flexural strength, sulphateattack, chemical attack, corrosion of the reinforcement bar etc and they are discussed briefly.Effective production of BC is achieved by carefully selecting, controlling and proportioning all ingredients. In order to achieve quality BC, optimum proportions must be selected, considering the characteristics of cement, aggregate quality, paste proportion, aggregate paste interaction, admixture type, dosage of bacteria and meticulous care in mixing and handling.

2.1 Fly Ash

Fly ash, flue ash, coal ash, or pulverised fuel ash (in the UK) – plurale tantum: coal combustion residuals (CCRs) – is a coal combustion product that is composed of the particulates (fine particles of burned fuel) that are driven out of coal-fired boilers together with the flue gases. Ash that falls to the bottom of the boiler's combustion chamber (commonly called a firebox) is called bottom ash. In modern coal-fired power plants, fly ash is generally captured by electrostatic precipitators or other particle filtration equipment before the flue gases reach the chimneys. Together with bottom ash removed from the bottom of the boiler, it is known as coal ash.

2.2 Silica Fume

Silica fume is an ultrafine material with spherical particles less than 1 μm in diameter, the average being about 0.15 μm. This makes it approximately 100 times smaller than the average cement particle.[4] The bulk density of silica fume depends on the degree of densification in the silo and varies from 130 (undensified) to 600 kg/m3. The specific gravity of silica fume is generally in the range of 2.2 to 2.3. The specific surface area of silica fume can be measured with the BET method or nitrogen adsorption method. It typically ranges from 15,000 to 30,000 m2/kg.[5]

2.3 Rice Husk Ash

Rice husk ash (RHA) is an abundantly available and renewable agriculture by-product from rice milling in the rice-producing countries. It has the highest proportion of silica content among all plant residues (Siddique, 2008; Xu, Lo, & Memon, 2012; Yalçin & Sevinç, 2001). A rice mill turns the paddy plant into 78% rice, 20% rice husk and 2% is lost in the process (Ash, 2010). The rice husk contains about 50% cellulose, 25–30% lignin and 15–20% silica (Ismail & Waliuddin, 1996). Hence, after the combustion, one-fifth to one-quarter of the rice husk will change into ash.

2.4 Calcium Nitrate

Calcium nitrate, also called Norgessalpeter or Norwegian salpeter, is an inorganic compound with the formula $Ca(NO_3)_2(H_2O)_x$. Both anhydrous and hydrated forms are colourless salts. Calcium nitrate is mainly used as a component in fertilizers, but it has other applications.

Nitrocalcite where manure contacts concre te or limestone in a dry environment as in stables or caverns. A variety of double salts are known including calcium ammonium nitrate decahydrate ($NH_4NO_3 \cdot 5Ca(NO_3)_2 \cdot 10H_2O$) and calcium potassium nitrate

2.5 Blended Concrete

The enhanced properties that are obtained due to blending of cement with different materials are,

1. Improved workability and pumpability.
2. Reduced water demand
3. Enhanced bleed control
4. Lower drying shrinkage and creep
5. Improved resistance to sulphate attack and chloride penetration
6. Reduced potential for Alkali Aggregate Reaction

III. MATERIALS USED AND MIX PROPORTION

The materials used in this investigation were ordinary portland cement, coarse aggregate of crushed rock with a maximum size of 20 mm, fine aggregate of clean river sand and potable water. The High Yield Strength Deformed bars of 10 mm diameter were used as the main reinforcement. The Mild Steel bars of 6 mm diameter were used as the stirrups.

3.1 Fine Aggregate

The fine aggregates used were clean, containing sharp and angular grains and well graded one. The natural river sand was used, tested and conforming to the specifications IS 2386 (Part II)-1963 (1996), IS 2386 (Part III)-1963 (1997), IS 2386 (Part IV)-1963 (1996) and IS 2386 (Part VI)-1963(1997). The test results obtained are tabulated in the following.

Physical properties of fine aggregate

Test Particulars	Results Obtained
Specific Gravity	2.53 ± 0.2
Fineness Modulus	2.85 ± 0.3
Bulk Density (kg/m3)	1800
Water Absorption	0.69 ± 0.4
Free Moisture Content	0.09% ± 0.2

3.2 Coarse Aggregate

The coarse aggregate occupies more than 50% - 60% of the volume of the concrete and their impact on various properties of the concrete isconsiderable. A good quality of crushed granite stones were used, tested and conforming to the specifications IS 2386 (Part III)-1963 (1997), IS 2386 (Part IV)-1963 (1996), IS 2386 (Part V)-1963 (1996), IS 2386 (Part VII)-1963(1996) and IS 2386 (Part VIII)-1963 (1991). The crushing strength value of the coarse aggregate was tested as per IS 9376-1979 (1997) and its impact value was tested as per IS 9377-1979 (1990). The guidelines for the tests on the coarse aggregate were also referred from Shetty (2003) and Rangwala (1997). The test results are tabulated in the following.

Physical properties of coarse aggregate

Sl. No	Test Particulars	Results Obtained
1.	Specific Gravity	2.60 ± 0.4
2.	Bulk Density (kg/m^3)	1600
3.	Aggregate Impact value (%)	11.2 ± 0.3
4.	Aggregate Crushing value (%)	24.95 ± 2
5.	Fineness Modulus	6.72 ± 0.2
6.	Water Absorption (%)	0.45 ± 0.4
7.	Free moisture content (%)	0.2 ± 0.1

3.3 Cement

Cement is a binding material which binds the constituents such as fine aggregates and coarse aggregates in the presence of water. The cement used was well grinded, easily workable and offers good resistance to the moisture. The cement used was 53 Grade OPC conforming to IS 12269-1987 (1997). The cement was tested as per IS 4031-1988 (1988) and the results are tabulated

Test Particulars	Results Obtained	Requirements of IS 12269-1987
Fineness (m^2/kg)	312 ± 20	Minimum 225
Initial Setting Time (min)	132 ± 5	Minimum 30
Final Setting Time (min)	193 ± 8	Maximum 600
Standard Consistency	26.37	-
Soundness (mm)	1	Maximum 10
Specific Gravity	3.15	-

3.4 Water

Water is a crucial and important ingredient of the concrete as it actively participates in the chemical reaction with cement and results in hardening of the concrete. The water used in this study was potable water. The potable water used was confirming to the requirements of IS 456-2000 (200**0**).

3.5 Fly Ash

The chemical and mineralogical composition of fly ashes depend on the characteristics and composition of the coal burned in the power plant. The burning of harder, older anthracite and bituminous coal typically produces Class F fly ash. This fly ash is pozzolanic in nature, and contains less than 20% lime (CaO). Possessing pozzolanic properties, the glassy silica and alumina of Class F fly ash requires a cementing agent, such as Portland cement, quicklime, or hydrated lime, with the presence of water in order to react and produce cementitious compounds . The principal constituents of Fly ash (Class F) obtained from Mettur Thermal Power Station (MTPS) was used in this study. The fly ash confirming to the requirements of IS 3812-1981(1998). The chemical composition of fly ash is as follows.

3.6 Reinforcement

High yield strength deformed bars confirming to grade Fe 415 of 10mm diameter rods were used as main reinforcements and 6mm diameter rods were used as stirrups at spacing 150mmc/c. The Figure 3.1 shows the details of thereinforcement and prepared concrète beams.

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3.7 Preparation of Test Specimen

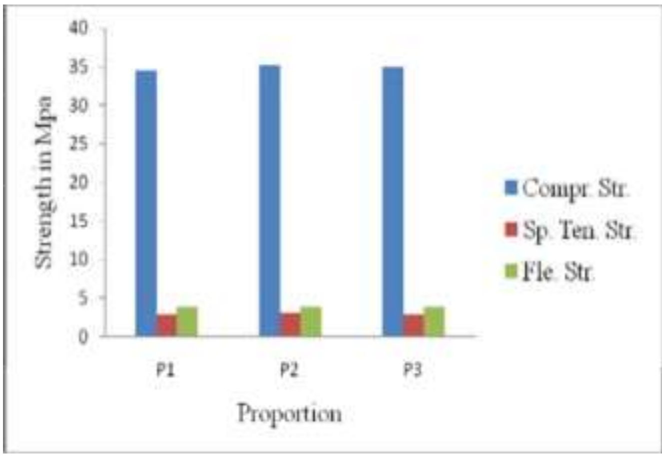
The standard 150 mm metallic cubes were used for the preparation of the concrete test specimen for determining the compressive strength as per IS 10086-1982 (1995). The standard cylindrical steel moulds measuring 150mm diameter and 300mm height were used for the preparation of the concrete test specimen to determine the tensile strength and corrosion attack as per IS10086-1982 (1995). The standard prism steel moulds of size 500mm x 100mm x100mm were used for the flexural strength test of plain cement concrete beams as per IS 10086-1982 (1995). The steel prism of size 1000mm x 100mm x150mm (inner dimensions) were used for the flexural strength test of reinforced cement concrete beams as per IS 10086-1982 (1995).

3.8 Compressive Strength of the Concrete

Compressive strength tests were carried out on 150mm x 150mm x 150 mm cubes as specified by IS 516-1959 (1989). This test was carried out using AIMIL compression testing machine of 2000 kN capacity at a uniform stress of 149 kg/cm2/minute after the specimen had been centered in the testing machine. The ultimate load (P) was noted down. The Figure 3.4 shows the photograph of compression testing machine set up. The compressive strength was calculated by using the Equation (3.2) (Antiohos et al 2007, Ezziane et al 2007, Ghrici et al 2007, Lubeck et al 2012 and Moulin et al 2001)

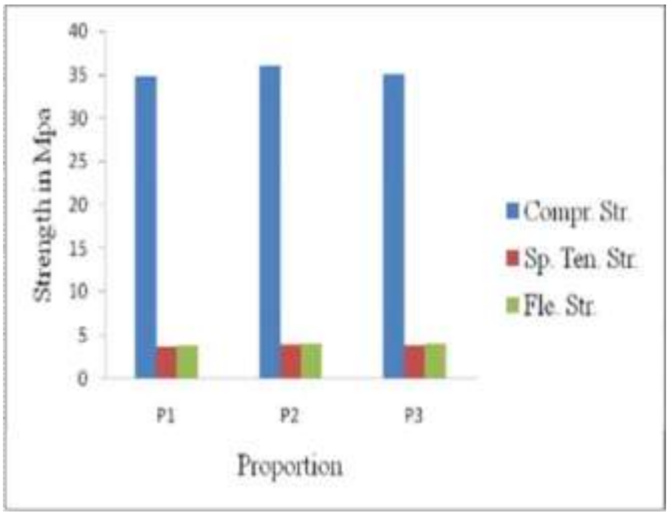
IV. OPTIMIZATION OF THE ADMIXTURES

Several experimental trials were conducted to optimize the quantity of the admixtures to be added for preparing the concrete starting with 1% to 25% in all the combinations. The following tables represent the various values obtained during the trial. Among the various trial results, the best result was obtained for the following combination and they are presented in the following Tables 4.1 to 4.6 for M25 grade of concrete.



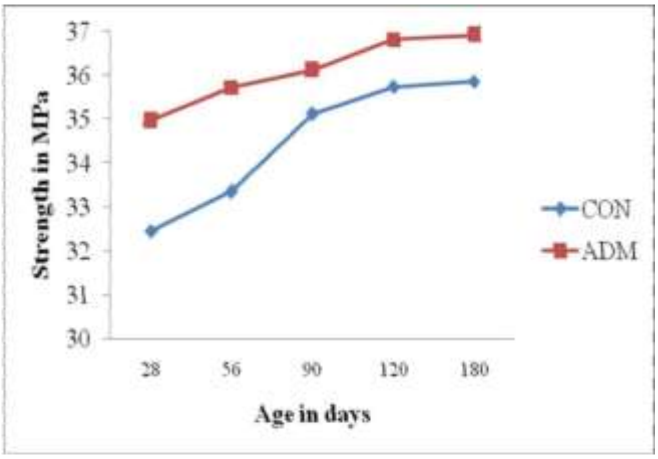
4.1 Durability properties of the concrete for various proportions for M25 grade of concrete

It was observed from the above results and Figure 4.1 and Figure 4.2, both the strength and durability properties were improved considerably by the addition of admixture. In which P1 observed the combination of 20.0% fly ash, 10.0% silica fume, 15.0% rice husk ash and 3.0% calcium nitrate, P2 observed the combination of 20.0% fly ash, 10.0% silica fume, 10.0% rice husk ash and 3.0% calcium nitrate and P3 observed the combination of 15.0% fly ash, 10.0% silica fume, 10.0% rice husk ash and 3.0% calcium nitrate and it was also observed that, for the combination of P3 a better result in terms of both the mechanical and durability properties were obtained comparatively with respect to the conventional concrete specimens which are presented in the table 4.7. Hence the study was carried out for 28 days, 56 days, 90 days, 120 days and 180 days for M25 grade of concrete.



4.2 MEASUREMENT OF WORKABILITY

The tests have been conducted to determine the workability of the fresh concrete and are discussed in detail in the following headings. The workability is also compared with that of the conventional concrete.



4.3 Slump Test

Slump test is the most commonly used method of measuring consistency of concrete which can be employed either in laboratory or at site of work. It is used conveniently as a control test and gives an indication of the uniformity of the concrete from batch to batch. It is observed that the repeated batches of the same mix, brought to the same slump, will have the same water content and water cement ratio, provided the weights of

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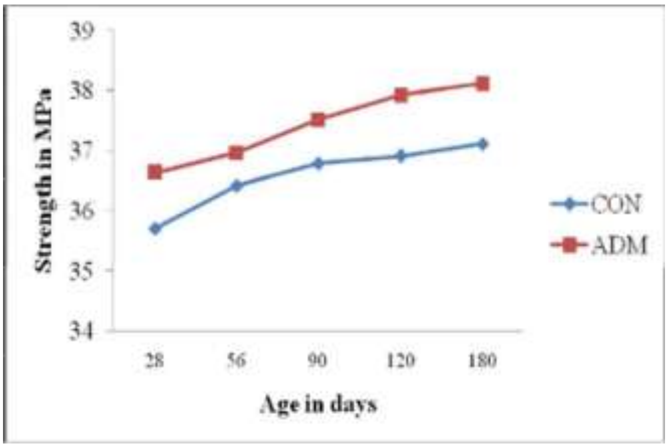
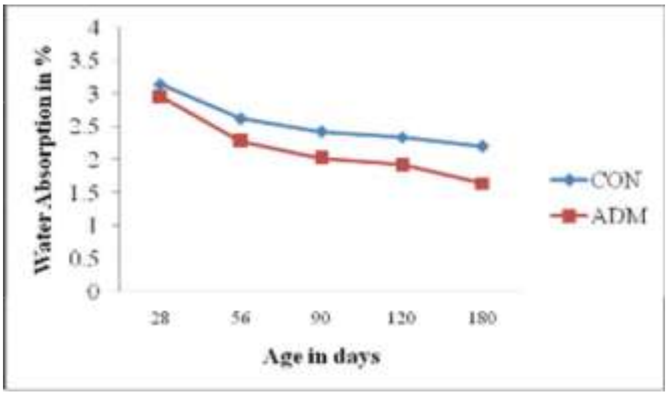
aggregate, cement admixtures are uniform and aggregate grading is within acceptable limits



4.4 Determination of Compaction Factor

The compacting factor test is designed primarily for use in the laboratory but it can also be used in the field. It is more precise and sensitive than the slump test and is particularly useful for concrete mixes of very low workability as it is normally used when concrete is to be compacted by vibration. Such dry concrete are insensitive to slump test. The values of the compaction factor for both the M25 and M30 grade of the concrete were presented in the Table 4.16 and Figure 4.6 depicts the compaction factor test in progress. When the cement particles were flocculated there was a friction between particle to particle and floc to floc. Hence the required compaction factor was obtained for both the grade of concrete.



4.5 Water Absorption of M25 grade of concrete

The water absorption of M30 grade of the conventional concrete is 3.14% after 28 days, 2.62% after 56 days, 2.42% after 90 days, 2.34% after 120 days and 2.20% after 180 days. The water absorption of the concrete prepared by replacing 15.0% fly ash, 10.0% silica fume, 10.0% rice husk ash and 3.0% calcium nitrate is 2.96% after 28 days, 2.28% after 56 days, 2.02% after 90 days, 1.92% after 120 days and 1.64% after 180 days.

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Load versus deflection values for M30 grade of concrete prepared by adding admixture

S. No	Load (KN)	Deflection in mm		
		LHS Obs.	Mid Span obs.	RHS Obs.
1.	0	0	0	0
2.	5	0.03	0.07	0.04
3.	10	0.18	0.30	0.16
4.	15	0.30	0.71	0.34
5.	20	0.44	1.09	0.51
6.	25	0.56	1.31	0.59
7.	30	0.71	1.60	0.73
8.	35	0.82	1.90	0.80
9.	40	0.90	2.22	0.92
10.	45	1.09	2.47	1.08
11.	50	1.17	2.80	1.14
12.	55	1.32	2.95	1.29
13.	60	1.39	3.21	1.43
14.	65	1.48	3.51	1.47
15.	70	1.68	3.90	1.69
16.	75	1.81	4.22	1.74
17.	80	2.08	5.61	2.04
18.	85	2.29	6.28	2.24
19.	90	2.71	6.60	2.66
20.	95	2.92	7.08	2.89
21.	100	2.98	8.07	2.92
22.	103.26	3.21	8.56	3.18

The first crack load was at 27 KN and the ultimate load was at 103.26 KN.

V. DURABILITY OF THE CONCRETE

The durability of the concrete can be defined as its resistance to the deteriorating influences of both external and internal agencies. A durable concrete is the one which performs satisfactorily under anticipated exposure conditions during its entire service life span. The materials and mix proportions used should be such as to maintain its integrity and to protect the reinforcement bar embedded in the concrete from corrosion (Fattuhi and Hughes 1986). Even though the concrete is a durable material requiring a little or no maintenance in normal environment but when subjected to highly aggressive or hostile environments it has been found to deteriorate resulting in premature failure of structures or reach as state requiring costly repairs. The main characteristics influencing the durability of the concrete is the permeability to the ingress of water, oxygen, carbon dioxide, chloride, sulphate and other potentially deleterious substances (Gambhir 2009).

5.1 PERMEABILITY OF THE CONCRETE

Permeability of concrete is the property by which water can penetrate into the pores of the concrete and in turn it may adversely affect the strength and durability properties of the concrete. When excess water in the concrete evaporates, it leaves voids inside the concrete element creating capillaries which are directly related to the concrete porosity. The quantity and volume of moisture which passes through the concrete depends on the concrete permeability. If the concrete becomes saturated with water then it is more vulnerable to frost action**.**

The permeability of M25 grade of the conventional concrete is 7.60 X 10-7cm/sec after 28 days, 6.60 X 10-7cm/sec after 56 days, 6.10 X 10-7cm/sec after 90 days, 6.00 X 10-7cm/sec after 120 days and

5.20 X 10-7cm/sec after 180 days.

5.2 SULPHATE ATTACK OF THE CONCRETE

The sulphate attack is caused by the chemical reaction between sulphate ions and hydration products. The result of the chemical reaction is calcium sulphoaluminate hydrate, commonly referred to as ettringite (3CaO.A12O3.3CaSO4.32H2O) which results in the reduction of bond strength and internal disintegration of the concrete. These solids (ettringite) have a very much higher volume up to 225% of the concrete specimen. As a consequence, stresses are produced in the concrete which may result in the breakdown of the cement paste and it ultimately results in the breakdown of the concrete. The sources of sulphate ion are such as sewage, salts in ground water, industrial waste, delayed release of the clinker during the cement production etc

5.3 CHLORIDE ATTACK OF THE CONCRETE

Chloride attack is one of the most important aspects for consideration when we deal with the durability of concrete. Chloride attack is particularly important because it primarily causes corrosion of reinforcement. The statistics have indicated that over 40 per cent of failure of structures is due to the chloride attack which further leads to corrosion. The chloride enters the concrete from cement, water, aggregate and sometimes from admixtures. Chloride can also enter the concrete by diffusion from the environment. The amount of chloride required for initiating corrosion is partly dependent on the pH value of the pore water in the concrete (Shetty 2011).

5.4 ACID ATTACK OF THE CONCRETE

The acid attack of the concrete is due to the presence of acids in subsoil and groundwater, acidic atmosphere in which the structure is built, acid stored in tanks, acid added during the manufacture of the concrete with or without the awareness. A pH value of less than 6 indicates the presence of acids in groundwater. Chemical attack generally occurs when calcium hydroxide present in the concrete is vigorously attacked. The acidic solutions both mineral (such as sulphuric, hydrochloric, nitric, and phosphoric chemicals) and organic (such as lactic, acetic, formic, tannic chemicals) are the most aggressive agents inducing chemical attack on the concrete. The loss of weight due to acid attack of M25 grade of the conventional concrete is 2.41% after 28 days, 2.12% after 56 days, 1.98% after 90 days, 1.91% after 120 days and 1.80% after 180 days. The loss of weight due to acid attack of the concrete prepared by replacing 15.0% fly ash, 10.0% silica fume, 10.0% rice husk ash and 3.0% calcium nitrate is 1.46% after 28 days, 1.31% after 56 days, 1.22% after 90 days, 1.17% after 120 days and 1.09% after 180 days.

5.5 CORROSION STUDIES

Corrosion is defined as the destruction of materials due to chemical reaction with the environment and also the loss of steel (reinforcement bar embedded in the concrete) due to the formation of the rust. The corrosion of the steel reinforcement is the depassivation of steel with reduction in the concrete alkalinity through the process of carbonation. Most of the materials undergo corrosion on exposure to natural environments or other artificial environments such as gases, liquids or moisture. The hazards to human life and economic losses occur due to premature deterioration and destruction of steel in buildings, bridges, culverts, pipes, marine and offshore structures, towers, water supply and sanitary fittings, electrical fittings etc (Santhakumar 2008).

VI. SUMMARY AND CONCLUSIONS

The first chapter, the introduction, discussed about the importance of the concrete prepared with the replacement of different admixtures. In this chapter, the objective of adding the admixture, types of admixtures etc are discussed. Finally the first chapter, the introduction, is concluded with a detailed objective of the project. The second chapter, review of literature presents an overview on the use and purpose of the admixture in the concrete. It also gives the observations and the importance of various parameters affecting the properties of the concrete like the effects of the concrete subjected to the durability properties such as sulphate attack, chloride attack, corrosion studies etc and mechanical properties such as compressive strength, tensile strength, flexural strength, permeability, etc by the addition of the various admixtures. The second chapter is concluded with the scope of the project, problem definition and proposed methodology of the research work.

In the third chapter, materials used for preparing the concrete samples, mix design, the properties of the various admixtures and the experimental procedure for carrying out various tests on the concrete are described in detail.

In the fourth chapter, the behaviour, results and discussions of using the various admixtures for the preparation of the concrete are studied and presented pertaining to the strength properties of the concrete.

In the fifth chapter, results and discussions about the durability properties of the concrete prepared by replacing the various admixtures for preparing the concrete are discussed in detail.

Finally in the sixth chapter, the conclusion on this experimental research work is given as well as suggestions on future developments are also provided.

Based on various and repeated trials, it was determined that by the replacement of the admixtures in the following proportions of 15.0% fly ash, 10.0% silica fume, 10.0% rice husk ash and 3.0% calcium nitrate with the cement, durability properties and strength properties of the concrete were improved.

6.1 SCOPE FOR FURTHER RESEARCH

1. This type of multi component blended concrete can be tried in some adverse conditions and structures exposed to severe conditions.
2. Further by adding five admixtures while preparing the concrete, the properties may be studied.
3. The studies may be prolonged for 5 years or 10 years and the properties of the concrete may be observed and studied for longer duration.
4. The slabs may be constructed by adding the admixtures and load versus deflection characteristics may be studied.

The concrete samples can be studied and analyzed after 10 years or 20 years through scanning electron microscopy (SEM analysis) and X-ray diffraction method.

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