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Effect of corrosion in different types of blended concrete

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ABSTRACT
Reinforced concrete is widely used for various types of structures. The corrosion of reinforcement decreases the strength and the service life of the structures. Reinforced concrete structures constructed in areas with chloride, sulphate and floride content are affected by corrosion. The aim of the study is to determine the effect of chloride induced corrosion on compressive strength of various types of blended concrete. For the experimental investigation blended concrete partially replaced with 10% metakaolin and Fly Ash 10%, 20%,30%, 40%,concrete blended with 10% metakaolin and10%, 20%, 30%, 40% GGBS , concrete blended with 10% metakaolin and 5%, 10%, 15%, 20% Rice Husk Ash are studied. The different concrete cube specimens are corroded in an accelerated corrosion setup. The compressive strength reduction and corresponding degree of corrosion are determined.
Keywords: accelerated corrosion, compressive strength, fly ash, GGBS,Metakaolin, Rice Husk Ash

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I. INTRODUCTION

Reinforced concrete is widely used in construction due to its low cost and easy availability.It is extensively used in the construction of buildings, airports, bridges, harbours, tunnels etc. Reinforced concrete structures in aggressive environments undergo deterioration and loses its long-term performance, reliability and durability. The aggressive environment can be due to chloride attack or carbonation attack. Chloride ions usually comes from marine environment, usage of de-icing salts in colder regions, usage of chloride contaminated aggregates or usage of chloride contaminated water in mixing of concrete. Improper or negligence in consideration of corrosion prone environments in design leave the structure prone to corrosion attack from the initial stage itself. Even though the corrosion occurs over a long period of time, but it still drastically affects the useful service life and functionality of the structure and sometimes it even leads to the failure of the structure. The increased maintenance and repair costs of corroded structures is also a serious concern.

Metakaolin ,Fly ash, ground granulated blast furnace slag and Rice Husk Ash are said to have durable properties. In this paper the chloride induced corrosion and its effect on the compressive strength of ordinary concrete, concrete partially replaced with a constant replacement of Metakaolin in all the mixes with Fly ash in 10%, 20%, 30% and 40%,concrete partially replaced with GGBFS in 10%, 20%, 30% and 40%.and concrete partially replaced with Rice Husk Ash in 5%,10%, 15%, and 20%.

II. EXPERIMENTAL PROGRAM

2.1 Materials

The ordinary portland cement (Ultra Tech) of 53 grade conforming to IS 12269: 2013 .The properties of cement are given in Table I. River sand corresponding to zone I conforming to IS 383 is used. To prepare the cube specimen for corrosion Sodium Chloride powder of 99.5% chlorine content is used. Hydrochloric acid of acidity35-37% is used to prepare reagent for cleaning the corroded specimen to clean the corroded specimen. Table 1 gives the properties of materials used for experimental program.

TABLE 1: Chemical composition of the materials

Material	Nacl powder			
Constituents	Chloride content on ignition	Loss on drying at 105^oc	Sulphate	Ammonia
Quantity (%)	99.5	1	<0.02	<0.006
Material	HCL			
Property	Molecular weight	Assay(acidimetric)	Weight per ml at 20^0C	
Value	36.46	35-37%	1.18g	

2.2 Mix Design and sample preparation

Mix is proportioned as per IS 10262:2019 an d IS 456:2000.Water cement ratio of 0.42 is used. To conduct the test on different types of concrete cube specimen of 150x150x150mm size are casted. Total of 78 cubes are casted for different types of concrete. The mixing of the concrete is done by rotary mixer and the cubes are vibrated on table vibrator to obtain good compaction. In all the cube specimens, a re-bar of diameter 12 mm m and length 25 cm, is kept at the centre of the cube as shown in Fig 1.

The initial weight of the re-bar is recorded before placing it in fresh concrete.

Figure 1: Samples for corrosion

2.3 Corroding the specimen

After curing, the cube specimens which are to be corroded are placed in sodium chloride solution for 10 days. After 10 days, the connections are made with electrical wire to join positive pole of the C supply to re-bar and negative pole to the copper electrode. Fig 2 below shows some of the cube specimens kept for corrosion . The theoretical time for passing the current is calculated using Faraday's Law.

Figure 2: Corrosion setup

$$m_t = \frac{t*I*M}{z*F}$$

m_t is theoretical mass loss ,t is the time in seconds. I is the current in ampheres,M is molar mass in g/mol ,z is the valency ,F is Faraday's constant in coulomb/mol.

For a given value of theoretical mass loss (m_t) in the above equation, the theoretical time required for corroding the specimen can be calculated. In this study, 10% mass loss of rebar in ordinary concrete is considered as the baseline for comparing it with other types of concrete (Locke, 2006) [16]. The current of 0.2A is passed through the setup with a potential difference of 12V (Bertolini, 2004) [17].

TABLE 2: Mix proportions

Specimen Id	Replaced by	% Replacement	Cement(kg)	FA(kg)	CA(kg)
OPC	-	-	448	787	983
FM1	Metakaolin,Fly ash	10%,10%	359	787	983
FM2	Metakaolin,Fly ash	10%,20%	314	787	983
FM3	Metakaolin,Fly ash	10%,30%	269	787	983
FM4	Metakaolin,Fly ash	10%,40%	224	787	983
GM1	Metakaolin,GGBS	10%,10%	359	787	983
GM2	Metakaolin,GGBS	10%,20%	314	787	983
GM3	Metakaolin,GGBS	10%,30%	269	787	983
GM4	Metakaolin,GGBS	10%,40%	224	787	983
RM1	Metakaolin,Rice Husk Ash	10%,5%	426	787	983
RM2	Metakaolin,Rice Husk Ash	1%,10%	403	787	983
RM3	Metakaolin,Rice Husk Ash	10%,15%	381	787	983
RM4	Metakaolin,Rice Husk Ash	10%,200%	359	787	983

III. EXPERIMENTAL RESULTS AND DISCUSSION

3.1 Compressive Strength

The compressive strength test is conducted in accordance with Indian Standard IS516:1959. All the cubic specimens are placed in compression testing machine in such away that the re-bar in the cubic specimen is normal to the direction of the compressive load. The compressive strength test for corroded and non-corroded specimen is conducted at the same time to eliminate the effect of increase strength due to age. The results are illustrated for compressive strength in Table 3. Due to corrosion, on the surface of the reinforcing bar corrosion deposits are formed which occupy more volume resulting in formation of micro-cracks. These micro cracks reduce the compressive strength of the specimen.

The variation of compressive strength for control and corroded specimen is shown in fig 3. The compressive strength 53.87 Mpa is maximum in 30% GGBS and metakaolin blended concrete .The percentage decrease in compressive strength of ordinary concrete is 24.4%.In case of partial replacement of cement with fly ash and metakaolin the maximum decrease in strength is 12.56% for blend of 10% fly Ash and metakaolin. In case of partial replacement of cement with GGBS and metakaolin the maximum decrease in strength is 7.76% for a combination of GGBS 10% and metakaolin 10%. In case of partial replacement of cement with Rice Husk ash and metakaolin the maximum decrease in strength is 9.89% with a blend of 10 % Rice husk ash and 10% Metakaolin.

3.2. Degree of corrosion

The degree of corrosion is calculated using the formula where,

$$m_r = \frac{m_{base} - m_{remain}}{m_{base}} * 100$$

mr is the real mass loss, m_{base} is the weight of the re-bar before placing it in fresh concrete and m_{remain} is the weight of the corroded re-bar after washing it bar with hydrochloric acid solution. The values for degree of corrosion are tabulated in Table 4 given below. The variation of degree of corrosion for different blended concrete is shown in fig 4.

The degree of corrosion is maximum of 11.11% in concrete partially replaced with 10% Rice Husk Ash and 10% metakaolin and it is minimum of 6.68% in concrete partially replaced with 40% GGBS and 10% Metakaolin. The degree of corrosion is less in GGBS Metokaolin blended concrete compared to other blends.

TABLE 3: Compressive Strength of Control and Corroded specimen

Mix Id	OPC	FM1	FM2	FM3	FM4	GM1	GM2	GM3	GM4	RM1	RM2	RM3	RM4
Control Specimen(Mpa)	45.22	49.81	47.79	44.22	42.46	47.11	49.29	53.87	50.41	46.54	47.72	46.23	43.22
Corroded Specimen(Mpa)	34.18	43.55	43.08	39.91	39.8	43.45	45.01	50.39	47.58	41.94	43.82	42.4	40.12

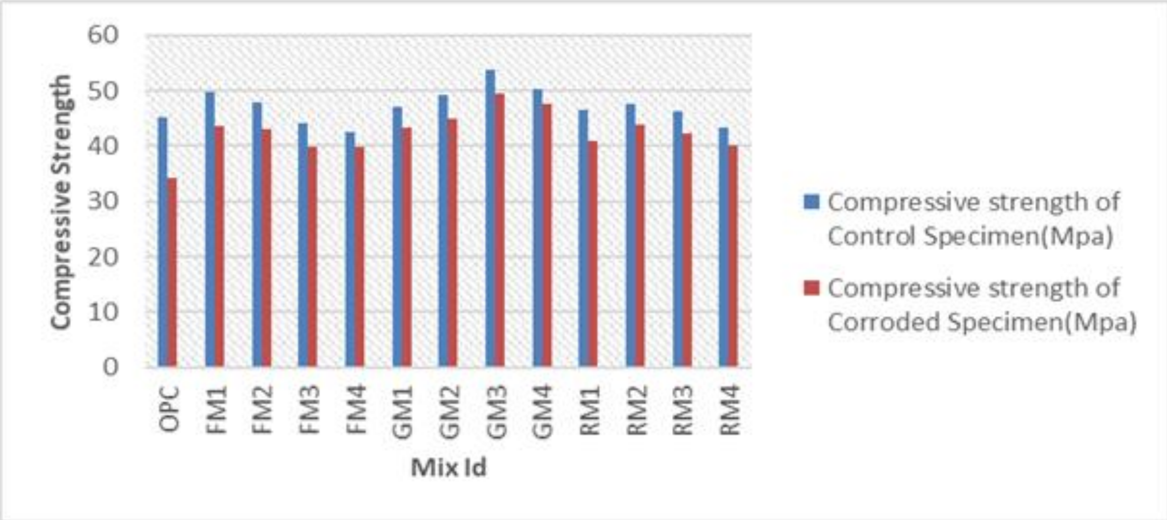

Figure 3: Compressive strength of control and Corroded Specimen

TABLE 4: Degree of corrosion of different types of blended concrete

Mix Id	OPC	FM1	FM2	FM3	FM4	GM1	GM2	GM3	GM4	RM1	RM2	RM3	RM4
m_{base}:Initial weight of bar (g)	100	100	100	100	100	100	100	100	100	100	100	100	100
m_f:remaining weight of bar (g)	89.48	89.74	90.19	91.29	92.69	89.84	90.49	91.72	93.22	88.9	89.14	90.83	91.04
Degree of corrosion (%)	10.52	10.26	9.81	8.71	7.31	10.16	9.51	8.28	6.68	11.1	10.86	9.17	8.96

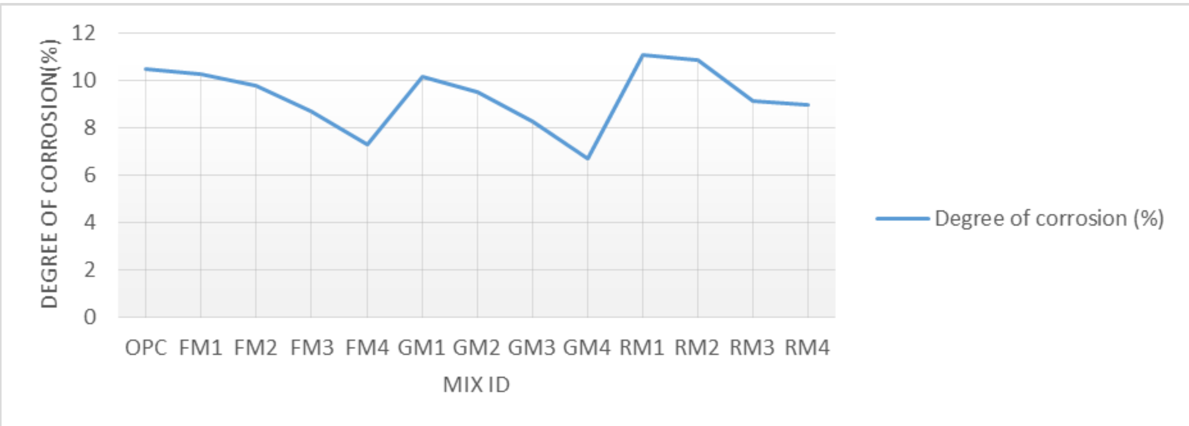

Figure 4: Degree of corrosion of different types of blended concrete

IV. CONCLUSIONS

- The compressive strength of all the mixes of blended concrete is higher than OPC .
- A higher strength reduction in OPC when exposed to chloride environment
- In all the blended mixes percentage reduction in strength due to corrosion is less compared to OPC.
- The percentage reduction in strength due to corrosion is less in all mixes of GGBS,metakaolin blended concrete compared to the other blended concrete.
- The degree of corrosion is more in Rice Husk Ash metakaolin blended concrete

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