A STUDY ON MECHANICAL PROPERTIES OF CONCRETE BY USING SUPPLEMENTARY CEMENTITIOUS MATERIALS

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ABSTRACT

Concrete technology is developing to bring a sustainable environment with the help of many innovative materials in concrete. This can reduce the amount of cement that is usually been used in concrete to avoid its negative effects on environment. Thus, many supplementary materials are being used these days to bring up a good material than cement or equally efficient material that can be used in concrete. One such try to examine the behaviour when they are used in the concrete are studied in this paper. The supplementary materials used here are bottom ash and quartz powder replacing fine aggregate and cement respectively at various percentage combinations. The results concluded that as the bottom ash when incorporated as fine aggregate, the strength of the concrete decreases. But when it is in a combination with quartz powder its strength is equivalent to control concrete. Thus, showing that quartz powder increases the strength parameters.

I. INTRODUCTION

Cement has been finely ground substance that serves as a primary binder in concrete. As cement is combined with water, a process called "hydration of cement" occurs, and the results of this reaction have binding properties. Cement books for 6–7% of global CO2 emissions and 93% of the total capacity. This has encouraged experts all over the world to look for cement replacements and use mineral admixture for partial cement replacement has shown promising results.

Toxic metals are still present in small amounts in industrial by-products. The widespread use of these for ground filling, dumping into lakes and wetlands, and even stockpiling poses significant health risks. When these mineral admixtures are used in concrete, though, the poisonous metals become immobilized as insoluble materials, rendering them harmless.

The potential of concrete for the duration of their operation under such environments to survive chemical attacks, weathering activity, abrasion or other kind of corrosion is called durability. Physical and chemical factors influences the quality of the concrete. Concrete degradation physical causes can be commonly categorized into surface wear and cracking. Surface wear is due to a difference in volume, structural loads and exposure conditions, caused by abrasion, corrosion and cavitations. In general, but not necessarily include chemical reactions between hostile substances in the atmosphere and concrete ingredients, the chemical factors that cause concrete degradation. This is attributed largely to an invasion on chloride. Porosity and the presence in concrete of intertwined pores also have an important impact on their mechanical strength and resilience.

In this study we utilized normal concrete prepared with cement, coarse aggregate of (20 mm) & (10 mm), fine aggregates of zone II and municipal tap water. Also mineral admixtures utilized as limited substitution of cement.. We computed the chemical and physical properties of ingredients utilized in concrete as per appropriate IS codes. The concrete mixes are planned for M40 grade. The IS code referred for NC mixes were 10269:2009.A number of experiments were conducted on various specimens according to IS code for determining strength.

Advantages of a high-range water reducer i.e super plasticizer and mineral admixtures are used to render NCC. The utilize of a super plasticizer is critical in the production of NCC, as it helps to achieve excellent filling, passing, and segregation resistance. Furthermore, mineral admixtures are used to get better strength and durability .It also aids in the achievement of strong segregation resistance. Mineral admixtures significantly enhance a variety of concrete properties, including durability.

Mineral admixture also reduces the environmental waste management issues that factories cause. In addition, the use of mineral admixture decreases the need for cement in the building industry, resulting in less cement use and less waste from cement manufacturing plants. As a result, mineral admixture not only increases the properties and durability of concrete, but it also has significant economic and environmental advantages.

Goal of Present Work is to employ GGBS ,Fly Ash , Silica fume and Metakaolin as partial replacement of cement and develop conventional concrete with steel fibers [0 to 1] for diverse water binder ratio (0.39 ,0.40,0.41,0.42 0.43 and 0.44). we have reported integration of Metakaolin ,fly ash ,GGBS and silica fume in ternary blended system (FA+MK ,FA+SF ,FA+GGBS) .Binary blended system concrete (FA,MK and GGBS) has also been reported. here Portland cement being the third component in ternary and binary blended system .

This would lead to more efficient use of these toxic by-products, which are also a big problem to dispose of. The ecosystem will be less harmed as a result of the successful use of these by- products, which will contribute to the creation of concretes with greater durable properties than standard concrete.

- Evaluation of the physicochemical characteristics of the materials in conventional concrete development
- Mix design has executed and workability test of NC and SCM Concrete as compliance to IS Code
- Compressive ,Flexure and Split tensile strength test for NC and SCM Concrete and its variations with steel fibre ,water binder ratio and super plasticizer

II. REVIEW OF LITERATURE

2.1 INTRODUCTION

This literature review is geared up on the strength aspects and the chapter also highlights a review on the important characteristic of normal concrete in the fresh and the hardened state including the testing procedures of strength tests.

- The manufacture of thick and impermeable concrete is one of the protective steps against reinforced steel corrosion.

- To prevent chloride ions from diffusing to the steel surface, preventive steps could be enhancing density of concrete. Fly ash (FA), silica fume (SF), and Grass Granulated blast furnace slag (GGBS) and Metakaolin can be utilised as supplementary to Portland cement concrete to augment its density and there by amplify its hindrance for corrosion
- Analysis of corrosion of reinforced steel in concrete necessitates measurement of chlorine evaluations and such inspections ensure that it does not reach a verge level to initiate corrosion
- Corrosion of reinforcing steel is chiefly endorsed to penetration of chloride ions to the steel surface.
- For quality management measure and to test the changes effected in the properties of new concretes, permeability determination of concrete with respect to chlorine is significant
- Chloride penetration is a sluggish process in concrete. It takes a long time to calculate the chloride diffusion coefficient It is difficult to determine it explicitly in a period outline. however modern chloride permeability test can give penetrability remarks in short time period

2.2 STUDIES ON CHLORIDE PENETRATION OF CONCRETE

Jaiswal, S. S., Picka,etal (2000) researched on Statistical approaches used to investigate the impact of concrete mix factors on durability. As an indirect test of chloride diffusivity, an updated version of ASTM C1202 is used. The mathematical study of the mix variable results was made easier with the help of two series of experiments. In one set of tests, regular aggregate grades were used, while in the other series, non-standard aggregate grades were produced to improve the effects of ionic flow tortuosity. In the conductivity test results, the volume fraction of aggregate was the most important experimental element, as predicted. However, interfacial transition zones and the tortuosity of ionic flow were found to have significant effects, heterogeneity of the ASTM C1202-94 test outcomes was also evaluated using statistical techniques.[1]

Afroze, M. (2002) in his master degree thesis discusses on corrosion conditions influencing chloride ion permeability and mathematical models used to assess chlorine influence. they discovered that in nearly all RCPT findings that there is an initial current reading at the start of the exam. The electrolysis of water in the saturated specimen is responsible for this. According to the classification scheme recommended in AASHTO T277, up to 4 days of wet-mat curing for 56 and 365day permeability test results on Lubbock concrete being improved [2].

Liang, M. T., etal (2003) studied consequence of several corrosive chemicals in concrete systems be shown using computer programme "Mathematica." The numerical effects of a concrete system exposed to several chemicals like chlorine ions ,carbon dioxide ion ,sulfate ion etc being studied .findings demonstrate that planned model is capable of accurately describe the appropriate parameters for numerical simulation. [3]

Lamichhane, K. (2005) in his doctoral thesis studied 12 different concrete mixes manufactured from 12 different coarse aggregate types (one for each aggregate type), with porosities varying from very low to relatively high. But for the coarse aggregate groups, all other parameters of both of these concrete types remained the same and SCM concrete mixes produced could easily be categorized as HP concretes. RCPT findings revealed that aggregate porosity had a significant impact on chloride penetrability in HP concretes, as calculated by a detailed series of tests. For further investigation, three aggregate/concrete forms corresponding to the lowest, mid-range, and highest porosities were chosen. The bulk paste regions of all representative concrete forms were represented by a paste-alone blend. On representative paste-alone and concrete specimens subjected to 28, 56, and 91-day RCPT, chloride profiling was conducted. A 2-dimensional (2D) concrete model was used to create an analytical model to simulate chloride migration during RCPT. The paste diffusion coefficients in mortar and concrete differed marginally but stayed within the same range at any given age, according to the simulation results. The predicted paste RCPT values and the analytical paste diffusion coefficients had a strong correlation. The proposed model was able to estimate the bulk paste diffusion coefficient with a reasonable margin of error, as shown by this correlation. Both the total average and paste chloride concentrations greatly increase with the increase in aggregate porosities, according to the short- and long-term simulations.[4]

Gardner, T. J. (2006) in his doctoral thesis found that Concrete's transport properties are essential considerations in assessing the serviceability of systems in chloride conditions. To effectively analyze and categorize concrete for use in chloride conditions, rapid chloride test methods are used. On mortar samples, split cell diffusion and migration experiments were performed, and the respective transport coefficients were determined. The largest difference between estimated migration and diffusion coefficients was observed in binder structures with higher chemical chloride binding ability .With increasing initial chloride concentration, the difference between the two parameters decreases. The operation of an electrical field reduces the chloride binding ability of cementitious matrices .Rapid chloride test results cannot be used to measure concrete diffusion coefficients for use in long-term prediction models unless the experiments have been optimized for this reason. [5]

III. METHODOLOGY AND EXPERIMENTAL PROGRAMME

3.1 INTRODUCTION

To accomplish the deliberate goal of the research, the experimental work was planned in logical way .Various experiments were done on the ingredient materials to determine fundamental properties such as specific gravity, gradation, etc .The various workability test were executed on fresh concrete .The casting of the various specimens was done systematically .The various concrete mixes with supplementary cementitious materials (SCM) incorporation were developed to evaluate strength properties.

3.2 MATERIAL CHARACTERIZATION

The various tests are performed to characterize the materials to be used for the production of normal concrete and specimens by means of supplementary cementitious materials. (SCM) .The constitute materials used as cement ,natural river sand ,coarse aggregate ,super plasticizers , steel fibre , fly ash ,Grass granulated blast furnace slag (GGBS) , Metakaolin , Silica fume etc . The Properties (Physical & Chemical) of Cement ,fine aggregates ,coarse aggregate ,super plasticizer ,steel fibre ,fly ash, GGBS ,Metakaolin , Silica fume etc were given in table 3.1 to 3.14.

3.2.1 Cement

Ordinary Portland cement (OPC43 Grade) as per IS 8112:1989 were being utilized . physical properties evaluated are tabulated in Table 3.1

3.2.2 Water

For concrete mixing and curing, the laboratory's potable water was being utilized

3.2.3 Aggregates

The natural river bed sand from Binawas Jodhpur available locally was utilized as fine aggregate .The coarse aggregate (from Kakani Jodhpur) of two sizes (20mm and 10mm) were used .The various tests requisite for the characterizing the aggregate were performed as per relevant IS Code .

3.2.4 Super plasticizer

An admixtures mainly influence the flow performance of concrete .Glenium 51 has been used as admixture. This admixture is appropriate for high performance concrete (HPC) where good durability is required .It is companionable with all type of cement .

3.2.5 Fly ash

Class f Fly ash obtained from "Suratgarh Thermal Power Station " .Rajasthan (India) .

3.2.6 Steel Fibres

Steel fibers were obtained in the experiment from binding steel wires used in tying reinforcement bars. Steel fibers had an aspect ratio of 75. These wires were cut properly to a length of 6 cm. Steel fiber had a diameter of 0.8 mm and a tensile strength of 1500 N/mm2.

3.2.7 Metakaolin

Metakaolin comes from a manufacturer called 20 Microns Limited Company. The metakaolin complies towards Pozzolona's minimum standards.

3.2.8 Silica Fume

Another substance utilized as an organic pozzolanic admixture is silica fume, also known as micro silica or condensed silica fume.

3.2.9 Grass Granulated blast furnace(GGBS)

The iron-making mechanism in a blast furnace creates ground granulated blast furnace slag. The slag is made up of lime, silica, and alumina, a certain oxides used in Portland cement however in different amounts and purchased from Ref steel Solutions, a supplier.

Table 3.1 : Physical Properties of Cement

S.No	Property	Value Obtained
1	Fineness(retained on 90?m sieve)	8.1
2	Specific gravity	3.1
3	Normal consistency	30
4	Initial setting time (minutes)	74
5	Final setting time (minutes)	210
6	Compressive strength	
	(i) 3 days	20.6
	(ii) 7 days	35.60
	(iii) 28 days	44.80

Table 3.2 : Properties of fine aggregate

S.No	Property	Value Obtained
1	Specific gravity	2.4
2	Bulk density (kg/m^3)	1570
3	Fineness modulus	2.72
4	Water absorption	1.8%
5	gradation	Zone II as per IS 383-1970

Table 3.3 : Sieve analysis of fine aggregate

S.No	IS Sieve	Cumulative weight retained (%)	Cumulative weight passing (%)	Zone II (IS 383 -1970)
1	4.75 mm	0.7	99.3	90-100
2	2.36 mm	14.8	85.2	75-100
3	1.18 mm	31.6	68.4	55-90
4	600	45.2	54.8	35-59
5	300	81.8	18.2	8-30
6	150	98.2	1.8	1-10
Sum of cumulative weight retained (%)		272.3		

3.2 DEVLOPMENT OF VARIOUS CONCRETE MIXES

In the Indian context, more than half of all concrete manufactured is of low to medium strength. As a result, standard concrete mixes with varying water binder ratios have been prepared with a wide variety of applicability. In this analysis, M40 Grade was chosen for different comparative purposes. Several blends (Binary & ternary) containing supplementary cementitious materials (SCM) have been prepared. The amounts of steel fibre and plasticizer used in each combination were varied to see what impact they had, and the results for different mechanical and Durability requirements were recorded.

3.3 CASTING OF CUBES , BEAMS & CYLINDERS

The total quantities needed for a series of cubes, beams, and cylinders are calculated. When the fresh mix was made, the slump and compaction factor tests were used to assess the workability of NC40. The formulated mix was poured into moulds that had been cleaned and oiled prior to concrete pouring. Moulds were demouled after 24 hours, based on concrete hardening. Various specimens were used, including a cube (150X150X150 mm), a beam (100X100X500 mm), and cylinders (150 mm diameter (D) and 300 mm height).

3.4 CURING

Samples were cured in normal tap water available in laboratory for a period of 3 ,7 and 28 days .later curing was executed in accelerated curing tank to accomplish desire degree of maturity and strength of concrete i.e equal to 28 day curing .with Non destructive Testing (Rebound Hammer and Ultra Sonic Pulse Velocity Tests)

IV. EXPERIMENTRAL RESULTS

4.1 EXPERIMENTRAL ANALYSIS

The Test on concrete ingredient materials (fresh and hardened concrete) are carried out as per the relevant IS code. Various concrete mixes of Grade M40 with Normal concrete and with incorporation of supplementary cementitious materials (SCM) are developed. Dosage of plasticizer and steel fibre were varied in each set of mixes.

4.1.1 MIX PROPORTIONS

The mix proportions of normal concrete designed as per IS 10262 as shown below in Tables

Table 4.1: Details of Concrete Mix Proportions with Metakaolin

S.NO	Series	Cement	Fine Aggregate	Water	Coarse Aggregate	Metakaolin	w/b	SP %	Fiber %
1	NC40	433	558	160	1270	0	0.37	1.5	0
2	NC40 MK5	411.35	534	190.52	1207	21.65	0.44	1.1	0.5
3	NC40 MK10	389.7	534	190.52	1207	43.3	0.44	1.1	0.75
4	NC40 MK15	368.05	534	190.52	1207	64.95	0.44	1.1	0
5	NC40 MK20	346.4	534	190.52	1207	86.6	0.44	1.1	0

Table 4.2 : Details of Concrete Mix Proportions with fly ash

S.NO	Series	Cement	Fine Aggregate	Water	Coarse Aggregate	Fly Ash	w/b	SP %	Fiber %
1	NC40	433	558	160	1270	0	0.37	1.5	0
2	NC40FA5	411.35	538	186.19	1216	21.65	0.43	1	1
3	NC40FA10	389.7	538	186.19	1216	43.3	0.43	1	0.5
4	NC40FA15	368.05	538	186.19	1216	64.95	0.43	1	0.75
5	NC40FA20	346.4	538	186.19	1216	86.6	0.43	1	0

4.1.1 WORAKABLITY OF NORMAL AND SCM CONCRETE

The properties of fresh concrete calculated in terms of workability.

The workability of concrete is computed by slump test and compaction factor method reported in tables below:

Table 4.3 : Workability of Concrete Mixtures with Metakaolin

S.NO	Series	w/b	SP %	Fibre %	Workability of fresh concrete	
					Sump (mm)	CF
1	NC40	0.37	1.5	0	92	0.90
2	NC40 MK5	0.44	1.1	0.5	80	0.84
3	NC40 MK10	0.44	1.1	0.75	79	0.80
4	NC40 MK15	0.44	1.1	0	87	0.88
5	NC40 MK20	0.44	1.1	0	86	0.89

Table 4.4: Workability of Concrete Mix with fly ash

S.NO	Series	w/b	SP %	Fibre %	Workability of fresh concrete	
					Slump (mm)	CF
1	NC40	0.37	1.5	0	92	0.90
2	NC40FA5	0.43	1	1	79	0.81
3	NC40FA10	0.43	1	0.5	88	0.89
4	NC40FA15	0.43	1	0.75	83	0.85
5	NC40FA20	0.43	1	0	86	0.88

4.1 STRENGTH STUDY OF VARIOUS MIXES

4.1.1 Cube Compressive Strength

Standard cubes of size 150 mm were cast for 3,7 and 28 days compressive strength of various mixes .compressive strength of three cubes with its average value and standard deviation were reported in this section

Table 4.5 : 3 day compressive strength with Metakaolin

S.no	Series	Cube1	Cube 2	Cube3	average value	S.D
1.	NC40	22.67	26.60	24.42	24.56	1.97
2	NC40MK5	24.13	25.55	25.33	25.00	0.76
3	NC40MK10	25.05	25.77	25.09	25.30	0.40
4.	NC40MK15	24.15	25.95	25.98	25.36	1.05
5.	NC40MK20	23.50	25.55	25.14	24.73	1.08

Table 4.6 : 7 day compressive strength with metakaolin

S.no	Series	Cube1	Cube 2	Cube3	average value	S.D
1.	NC40	34.88	36.19	37.50	36.19	1.31
2.	NC40MK5	36.12	37.23	39.66	37.67	1.81
3.	NC40MK10	40.12	41.03	41.10	40.75	0.55
4.	NC40MK15	35.66	37.98	38.67	37.44	1.58
5.	NC40MK20	34.01	36.98	37.68	36.22	1.95

V. CONCLUSIONS

In this chapter we highlight the important conclusions based on experimental, and observation of various destructive and non-destructive test conducted in laboratory for strength on various mixes of conventional concrete grade M40 and with mineral admixtures incorporated concrete specimens. Dosage (%) of super plasticizer and steel fiber has been varied in each specimens to enhance varies mechanical properties.

- Mineral admixture (GGBS, Fly Ash, Metakaolin, and Silica fume) was used as a supplementary cementitous material (SCM) in this analysis, with differing percentages as cement substitution. The issues involved with their disposal are dealt with in a more environmentally sustainable way
- The use of a super plasticizer fixed the issue of reduced workability and increased slump value, while steel fiber dosage increased compressive, flexural, and split tensile strength up to a certain limit of integration with concrete.

- Compressive strength of various normal concrete (NC40) and SCM Concrete made with locally available materials give an idea about the standard deviations in the laboratory ranging with 0.12 (NC40FA10GGBS20) to 4.05 (NC40FA10)
- The laboratory results shows about 15 % to 27 % higher strength than target mean strength for grade M40 with normal and Supplementary cementitous materials (SCM) concrete
- The flexure strength of NC and SCM Concrete mixes was found lower than standard codal strength i.e $0.7\sqrt{fck}$ However flexure strength reaches about to 60 % to 70 % of 28 days strength within seven days.

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